

## Calculations of IAEA-CRP-6 Benchmark Case 1 through 7 for a TRISO-Coated Fuel Particle

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### 1. Introduction

IAEA-CRP-6 is a coordinated research program of IAEA on **Advances in HTGR fuel technology**. The CRP examines aspects of HTGR fuel technology, ranging from design and fabrication to characterization, irradiation testing, performance modeling, as well as licensing and quality control issues.

The benchmark section of the program treats simple analytical cases, pyrocarbon layer behavior, single TRISO-coated fuel particle behavior, and benchmark calculations of some irradiation experiments performed and planned. There are totally seventeen benchmark cases in the program. Member countries are participating in the benchmark calculations of the CRP with their own developed fuel performance analysis computer codes. Korea is also taking part in the benchmark calculations using a fuel performance analysis code, COPA (COated PArticle), which is being developed in Korea Atomic Energy Research Institute.

The study shows the calculational results of IAEA-CRP-6 benchmark cases 1 through 7 which describe the structural behaviors for a single fuel particle.

### 2. Development of COPA-MECH

The TRISO-coated fuel particle consists of a kernel, a buffer, an inner pyrocarbon (IPyC) coating layer, a silicon carbide (SiC) barrier layer, and an outer pyrocarbon (OPyC) coating layer as shown in Figure 1. The SiC layer can be assumed to be elastic. The SiC layer is considered to remain unchanged under irradiation and experience no significant change in its mechanical properties during life. Under fast neutron irradiation, the PyC layer first shrinks and then swells in the radial direction, and continually shrinks in the tangential directions. The PyC layer experiences irradiation-induced creep as well.

The mathematical modeling on thermo-mechanical behaviors of a TRISO-coated fuel particle is set up for the three coating layers [1]. The solution can be obtained by a combined method of a closed form solution method [1, 2] and an explicit solution method [3]. Using the solution, a FORTRAN program, COPA-MECH, was developed to calculate the stresses and strains of the three coating layers.

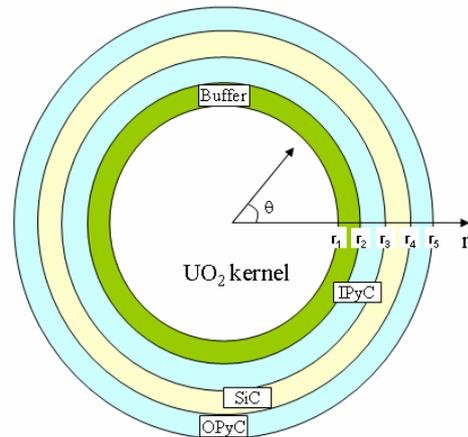


Figure 1. A TRISO-coated fuel particle.

### 3. Benchmark Case 1 through 7 of IAEA-CRP-6

Case 1 is for elastic SiC. The particle has a kernel, a buffer, and only a SiC coating layer. The SiC coating layer is elastic. Case 2 is for a simple BISO. The particle has a kernel, a buffer, and only an IPyC coating layer. Case 3 is for IPyC and SiC composite without fluence. The particle has a kernel, a buffer, and two coating layers, IPyC and SiC. Case 4a is for IPyC and SiC composite with no creep and constant swelling. Case 4b is for IPyC and SiC composite with constant creep and no swelling. Case 4c is for IPyC and SiC composite with constant creep and constant swelling. Case 4d is for IPyC and SiC composite with constant creep and fluence-dependent swelling. In Case 4, the particle is the same one as in Case 3. Case 5 through 8 are for a TRISO. In Case 5, the particle has a kernel whose diameter is 350  $\mu\text{m}$ . In Case 6, the particle has a kernel whose diameter is 500  $\mu\text{m}$ . In Case 7, the particle is the same as in Case 6 except that the pyrocarbon BAF is increased to 1.06.

Dimensional and material data for Case 1 through 7 are presented in the reference 4.

### 4. Results

Table 1 shows the maximum tangential stresses of the SiC layer in Case 1 through 3 calculated with the codes COPA-MECH, PARFUME (USA), and STRESS3 (UK).

The results are in good agreement except the PARFUME result in Case 3. Figure 2 presents the radial stress between the IPyC and SiC layers, and the maximum tangential stresses of the IPyC and SiC layers in Case 4d. The results from COPA and PARFUME shows a little disagreement when the fluence is between  $0.5 \times 10^{25}$  and  $0.8 \times 10^{25}$  n/m<sup>2</sup>. Figures 3 through 5 are the maximum tangential stresses of the IPyC and SiC layers in Case 5 through 7, respectively. The tangential stresses of the IPyC layer from COPA and PARFUME are in good agreement all over the fluence range in Case 5 through 7. However, the tangential stresses of the SiC layer do not agree when the fluence is between  $0.5 \times 10^{25}$  and  $2.6 \times 10^{25}$  n/m<sup>2</sup>. Table 1 shows the disagreement of the SiC tangential stress from COPA and PARFUME. This disagreement will be easily checked and corrected because it consistently appears at the intermediate fluence.

Table 1. Maximum tangential stress (MPa) of SiC the layer in Case 1 through 3

Case	COPA	PARFUME	STRESS3
1	125.19	125.19	125.3
2	50.20	50.20	50.2
3	104.38	108.58	104.3

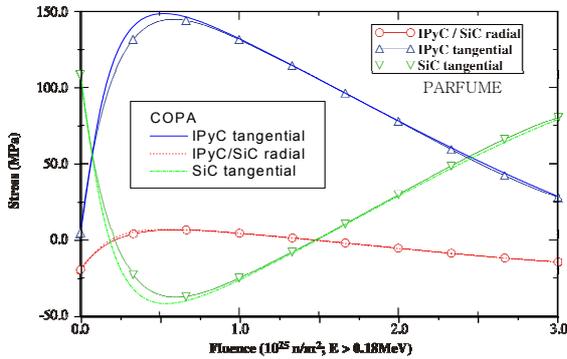


Figure 2. Radial and tangential stresses of Case 4d.

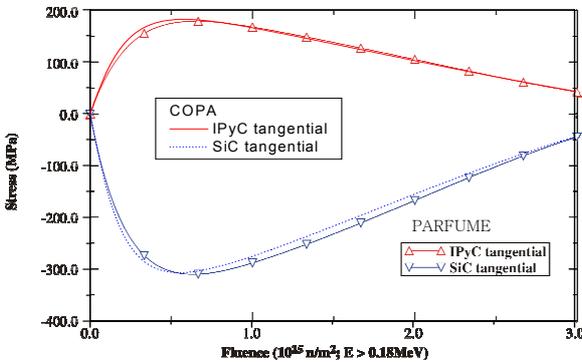


Figure 3. Tangential stresses of Case 5.

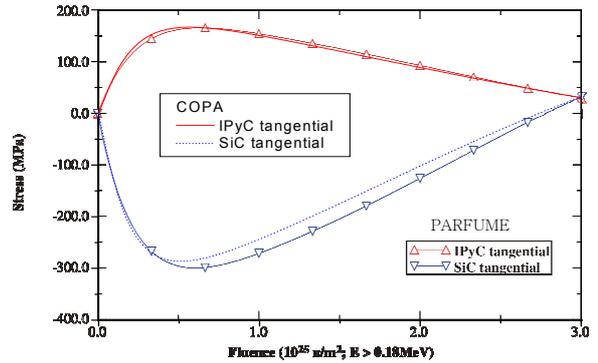


Figure 4. Tangential stresses of Case 6.

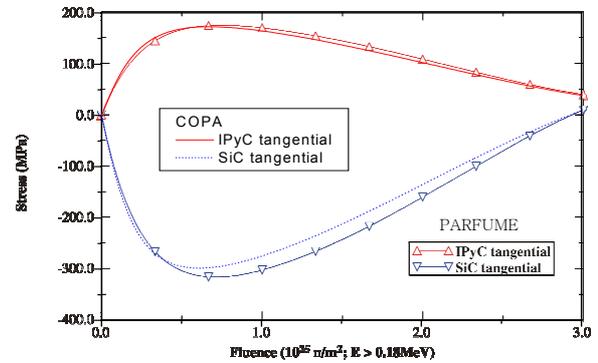


Figure 5. Tangential stresses of Case 7.

#### 4. Conclusion

From the calculations of the IAEA-CRP-6 benchmark Case 1 through 7 for a TRISO-coated fuel particle, the following conclusions are made:

1. In Case 1 through 3, the maximum tangential stresses from COPA, PARFUME, and STRESS3 agreed well except PARFUME result in Case 3.
2. In Case 4d, the stresses from COPA and PARFUME showed a little disagreement at the fluence of  $0.5 \times 10^{25}$  to  $0.8 \times 10^{25}$  n/m<sup>2</sup>.
3. In Case 5 through 7, the tangential stresses of the IPyC layer from COPA and PARFUME are in good agreement all over the fluence range, but the tangential stresses of the SiC layer do not agree consistently at the fluence of  $0.5 \times 10^{25}$  to  $2.6 \times 10^{25}$  n/m<sup>2</sup>.

#### Acknowledgement

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