Stress Analysis of a TRISO-coated Fuel Particle

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1. Introduction

A TRISO-coated fuel particle is a basic element of HTGR fuel. The integrity of the particle should be assured during life. For that reason, many thermal and mechanical analyses of a TRISO-coated fuel particle have been performed until now [1-5]. The study shows the stresses of the coating layers of a TRISO-coated fuel particle under loading using ABAQUS.

2. Stress Analysis

The finite element model deals with the stresses in the three layers of the TRISO-coated fuel particle: the inner pyrocarbon (IPyC) layer, the silicon carbide (SiC) barrier layer, and the outer pyrocarbon (OPyC) layer. The finite elements in the model are shown in Fig. 1. The elements are axisymmetric quadrilaterals with four nodes (element type CAX4I in ABAQUS). The thicknesses of the IPyC, SiC and OPyC layers are 40, 35, and 43 μm, respectively. The kernel diameter and buffer thickness are 195 and 100 μm, respectively. Fission gas pressure is applied to the inner surfaces of the IPyC layer. The internal pressure was ramped linearly from zero at the beginning of irradiation to a final value of 23.7 MPa. A constant external pressure of 6.4 MPa was applied to the outer surfaces of the OPyC layer. The stress analysis of a TRISO-coated fuel particle is performed through the time integration of the viscoelastic behavior of the coating layers.

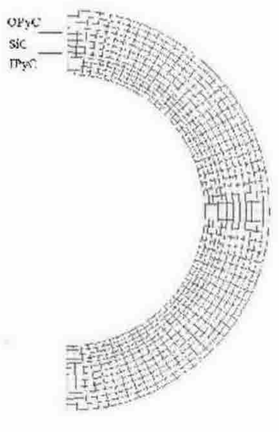

Fig. 1 Finite element model for a TRISO-coated fuel particle

The PyC and SiC layers are assumed to be isotropic. The SiC layer is assumed to be elastic. The SiC 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. And also, the PyC layer experiences irradiation-induced creep. The data related to the material properties of layers were obtained from a CEGA report [6].

3. Results

Stress and strain history of each coating layer was calculated. Fig. 2 shows von Mises stresses of the coating layers. The von Mises stress at the interface between IPyC and SiC layers is the greatest. It means that failure is most likely at the interface. Radial stresses rapidly decrease due to the high creep rate of the PyC layers. Tangential stresses also rapidly decrease. Creep of the PyC layers relaxes the stresses of the layers.

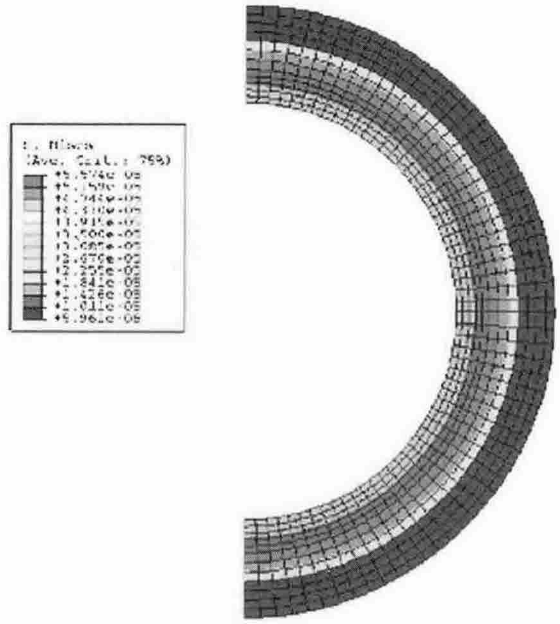

Fig. 2von Mises stress of a TRISO-coated fuel particle

The dependence of the thermal properties such as thermal conductivity, density, and specific heat on irradiation, BAF (Bacon Anisotropy Factor), and temperature must be specifically identified in order to include thermal analysis.

4. Conclusion

From the stress analysis of a TRISO-coated fuel particle, the following conclusions are made:

1. Failure is most likely to initiate at the interface between IPyC and SiC layers.
2. Creep of the PyC layers relaxes the stresses of the layers.
3. Data for thermal properties are needed to be clearly determined to complete the thermal and stress analysis for a TRISO-coated fuel particle.

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