STRESS ANALYSIS OF COATED PARTICLE FUEL IN GRAPHITE OF HIGH-TEMPERATURE REACTORS

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The PArticle Stress Analysis (PASTA) code was written to evaluate stresses in coated particle fuel embedded in graphite of high-temperature reactors (HTRs). Existing models for predicting stresses in coated particle fuels were extended with a treatment of stresses induced by dimensional change of the matrix graphite and stresses caused by neighboring particles.

PASTA was applied to two practical cases in order to evaluate the significance of this model extension. Thermal hydraulics, neutronics, and fuel depletion calculation tools were used to calculate the fuel conditions in these cases. Stresses in the first fuel loading of the High-Temperature Engineering Test Reactor (HTTR) and in the fuel of a 400-MW(thermal) pebble bed reactor were analyzed.

It is found that the presence of the matrix material plays a significant role in the determination of the stresses that apply to a single isolated TRISO particle as well as in the transmittal of the stresses between particles in actual pebble designs.

I. INTRODUCTION

The fuel design for nearly all high-temperature reactors (HTRs) currently planned and investigated is largely based on experience gained primarily in German research reactors1 during several decades (AVR, THTR, Dragon designs, etc.). These designs of the pebble bed type contain several hundreds of thousands of pebbles that form a porous bed, which is cooled with helium gas. The graphite pebbles, with a diameter of 6 cm, contain the nuclear fuel within their fueled region of 5-cm radius. This fueled region consists of a graphite matrix containing tens of thousands of TRISO-coated particles. The TRISO particles have a UO₂ (or UC) kernel at their very center. Adjacent to the kernel is a porous carbon buffer layer, which is coated with an inner pyrolytic carbon (IPyC) layer, a silicon carbide (SiC) layer, and an outer pyrolytic carbon (OPyC) layer. These coatings provide the primary containment of the fission products that are generated in the fuel kernel. As a consequence, numerous publications on integrity and performance of the TRISO-coated particle can be found in the literature since the 1960s (Ref. 2), ranging from stress analysis investigations3 to recent fully integrated fuel performance models.4–9

Trends in the intended operating conditions of the very-high-temperature reactor10 (VHTR), such as higher fuel temperatures and higher discharge burnup values, call for a reconsideration of these earlier fuel and reactor designs. Of particular interest are the stresses in the