AGR Core Component Failure Predictions using COMSOL Multiphysics®

Case study

Cracking of graphite components is proving a potential limiting mechanism in terms of station life for our client's advanced gas cooled reactors. EASL are assisting our client to understand the behaviour of post-irradiated induced cracking of a graphite fuel brick. A multilayer partial fuel channel has been modelled to predict the failure of interacting graphite components in the central region of the core. EASL's work now means that the evolution of stress and its effect on the failure mechanism of different graphite components is now understood. This is invaluable information to our client in preparing safety cases to secure on-going operation of these reactors and therefore future generation revenue.

Understanding and owning the problem

Damage tolerance of advanced gas cooled reactor (AGR) nuclear graphite fuel bricks is based on the location of failure within the brick. A single keyway root crack (KWRC) in the brick may not be a life-limiting issue. However, a KWRC may induce stresses at locations within the brick or in other components where failure may be critical for the safe operation of a reactor.

The stress pattern during the life of an AGR graphite fuel brick shows complex behaviour. A graphite brick undergoes two different phases of stress (tensile and compressive) at both its bore and periphery. This stress reversal occurs at a particular region of time which is called the turnaround time. The tensile stresses after turnaround/stress reversal are expected to cause KWRC. Following generation of a KWRC, further opening of the crack may destabilise the keying system and may produce undesirable interaction between different graphite components. This may lead to further cracking within the vicinity of the cracked fuel brick and thereby limit the operating life of the reactor.

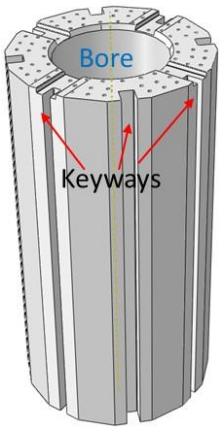

Figure 1 Typical example of an AGR fuel brick

Assessment of life expectancy of nuclear graphite components is a challenging task which involves dealing with highly non-linear material properties. The assessment is nearly impossible with conventional analytical modelling and requires a sophisticated FE package which can handle such highly non-linear behaviour smoothly.

Further, to fully understand the implication of the undesirable interaction, it was necessary to assess multicomponent modelling through the life of the AGRs.

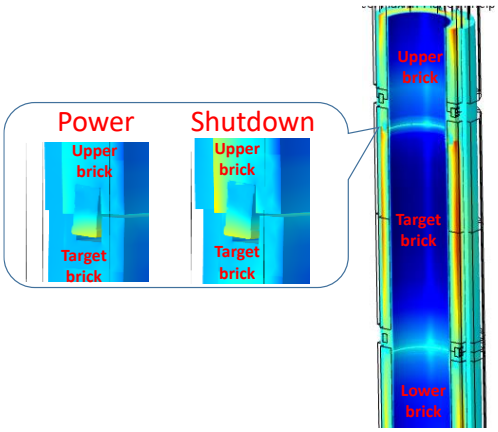

Figure 2 Three brick multilayer simulated model

Our solution and the outcome

Taking advantage of the fuel brick symmetry, a simplified three brick multilayer model has been developed in COMSOL Multiphysics® to simulate the interaction between inter-brick components including sealing ring keys and the sealing ring groove wall following a KWRC. The effect of the interaction on stress behaviour and hence failure of graphite components have been studied by simulating both at-power and shutdown conditions with appropriate modelling and boundary conditions including contact conditions.

Multiple loading conditions have been applied as a temporal and spatial distribution of neutron damage dose, irradiation temperatures and radiolytic oxidation effects (weight loss). The weight of the bricks above in the channel and self-weight of the fuel brick have also been considered.

Post-simulation, the behaviour of graphite components has been analysed both qualitatively and quantitatively. The stresses are compared with predefined critical stresses to predict further failure of the fuel brick or other graphite components.

Other applications

EASL always work with clients to identify cost effective solutions to operational challenges.

If you would like to discuss how EASL can help your business please get in touch.

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