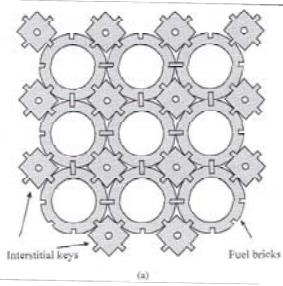


Internal strain measurement in graphite and glass

Soheil Nakhodchi, David Smith



Abstract

Graphite is used as a moderator, reflector and structural component in power plants and glass is used mostly in immobilization of high level radioactive wastes. The level of the internal stresses/strains in these structures has a critical role in their structural integrity. In this research, the feasibility of using the deep hole drilling (DHD) technique to measure internal stresses/strains in graphite is investigated and applicability of the technique to glass is under exploration. Finite element analysis and laboratory experiments were used for the evaluation.

FE analysis

Objective: Numerical evaluation of the capability of the deep hole drilling (DHD) method to measure thermal stress/strain distributions in AGR graphite bricks.

Thermal stresses: An AGR graphite brick - Figure 1 - was simplified to a hollow cylinder and a steady state thermal gradient was imposed on the FE model. Figure 2 shows thermal stress distribution in the hollow cylinder.

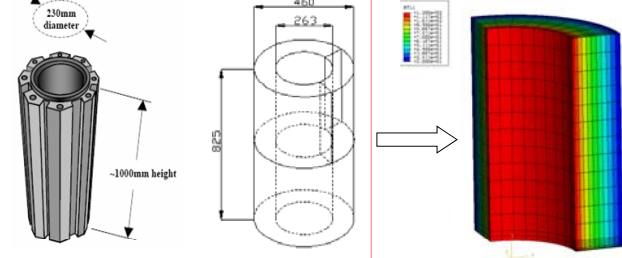


Figure 1 Graphite Brick

Figure 2 Thermal stress in hollow cylinder

DHD simulation: DHD was simulated in the mid-height of the cylinder to measure through the thickness thermal stress distribution. Figure 3 shows the mesh in the DHD simulation and the DHD location.

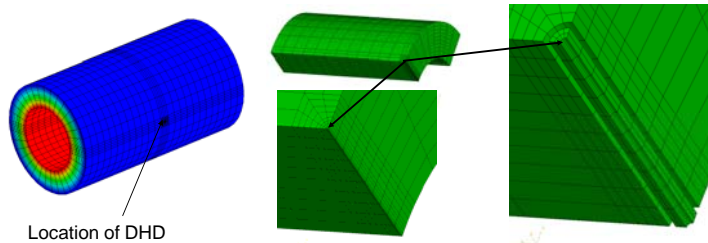


Figure 3 Location of the DHD simulation and FE mesh for the DHD simulation.

Changing material properties: Variation of E in the irradiated graphite was considered as a multilayer model. The thickness of the cylinder was subdivided into 10 layers and to each layer an individual E was assigned. This is shown in Figure 4.

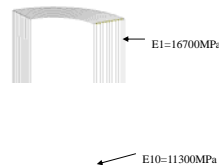


Figure 4 Multilayer model

FE Results: DHD simulations using a constant value of E equal to 17GPa can be seen in Figure 5. In addition, simulations in the multilayer model are compared with their corresponding FE predictions in Figure 6.

FE analysis showed that DHD technique is able to measure thermal stress and can also measure the average of the stresses when there are material property variations.

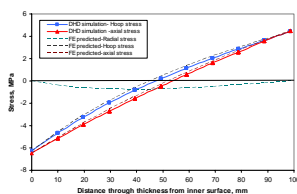


Figure 5 DHD simulation with E=17GPa

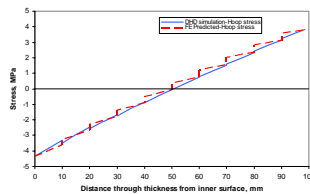


Figure 6 DHD simulation in multilayer model.

Concluding remarks: FE analysis and laboratory tests have demonstrated the capability of the DHD technique for measurement of the stress/strain distribution in graphite.

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Laboratory DHD measurement

Objective: Experimental evaluation of the DHD technique in measurement of stress/strain distributions in graphite.

Materials: Two types of graphite were used, PGA graphite and PG25 porous graphite. In PGA graphite Young's modulus is different in different directions and consequently samples were cut from blocks (Figure 7) in two directions. Samples were then strain gauged -Figure 8.

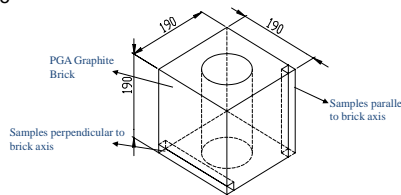


Figure 7 Samples extracted from graphite block

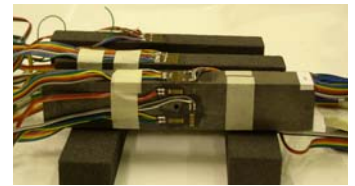


Figure 8 Rectangular graphite beams strain gauged ready for testing

Experiments: A known strain field was applied to the graphite rectangular beams by subjecting them to four-point bending. This is illustrated in Figure 9. The upper surface of the beam is in compression and bottom surface in tension. The deep hole drilling method was used to measure the applied strains through the depth of the beams, i.e. a reference hole was introduced through the beam and the hole distortion measured. Both PGA and PG25 porous graphite were done. Results were then compared with measured surface strains.

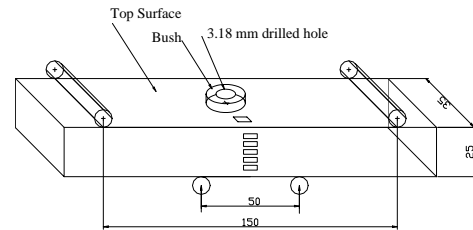


Figure 9 Graphite beam subjected to 4 point bending

Results: Measured longitudinal strains are shown in Figure 10 for the PGA graphite and in Figure 11 for the PG25 porous graphite.

The agreement between the measured surface and internal strains in the PGA graphite is excellent. The internal strains in the porous graphite illustrate greater variations from expected values. This has been shown to be a consequence of the highly porous nature of the graphite. Nevertheless, the research has shown that internal strains can be reliably measured in graphite.

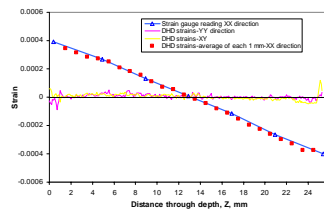


Figure 10 Measured strains in PGA graphite

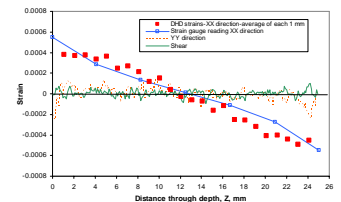


Figure 11 Measured strain in PG25 porous graphite