Evaluation of Waste Package Degradation Resulting from Metallic Corrosion

Research area: Waste and Fuel Management

PI: Haris Paraskevoulakos

Partners: Diamond Light Source

Contact details: cp13846@bristol.ac.uk

The Challenge

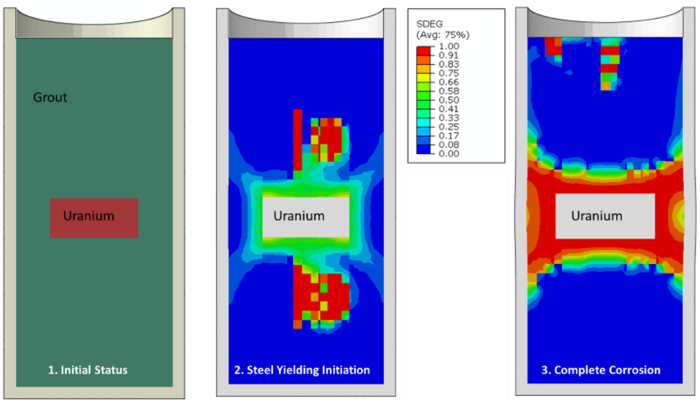
Within the UK, nuclear waste is classified according to the levels of radioactivity in three groups: High Level Waste (HLW), Intermediate Level Waste (ILW) and Low Level Waste (LLW). ILW mostly consists of metallic fragments arisen during the fuel decanning process. These metallic fragments are stored in 500L stainless steel drums (Figure 1) and are subsequently encapsulated in grout. Based on this waste treatment route, a solid matrix is generated, and the waste is expected to be immobile and safe.

Due to malfunctions having occurred during the early era of nuclear waste packaging, a considerable amount of uranium is known to be present within the drums. Recent inspections on a part of the ILW drums being currently stored in Sellafield, the principle British nuclear waste storage facility, revealed the presence of bulges on the stainless steel surface of several drums.

The distortion has been attributed to the corrosion-induced volume expansion of the encapsulated metals. Consequently, concerns have been risen about the long-term safety of the packages. Is there a chance of containment's failure? Does the grout keep the waste immobile? What is the extent of internal metallic corrosion?

Figure 1

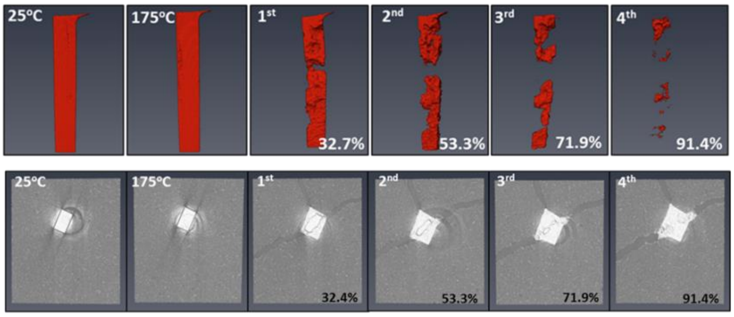
Figure 2



Characteristic FE model showing the evolution of grout cracking as the corrosion—induced volume expansion progresses in the interior of the drum.

University of BRISTOL

Figure 3



Sequential XRT measurements of mini ILW—simulant drums being artificially corroded in DLS. The upper set of images shows a single view of the encapsulated uranium matchstick being progressively corroded, while the lower part of images illustrates a view of the grout being cracked throughout corrosion evolution. The experimental cycle ID and the corresponding corrosion percentage are provided on top and bottom of each image respectively.

The Solution

Based on modern technology, monitoring the interior of the existing ILW drums without breaking the containment is not plausible. Also, dismantling the problematic drums to reveal the interior state is not approved, while replicate systems which could be used for research purposes are not available. The behaviour of ILW-simulant systems as encapsulated metallic corrosion progresses in the grout core has been studied using two alternative routes: Finite Element Modelling (FEM) and X-Ray Tomography (XRT). FEM is a predictive tool which was implemented to simulate simple forms of waste packages and evaluate the degradation of the encapsulants as internal volume expansion progresses.

Since the distribution and the size of the encapsulated metals within the grout core is random, simplistic models were built in accordance with miniaturised systems created by industrial collaborators as part of their experimental program. The models revealed that grout cracks after only limited volume expansion has occurred, i.e. at the very early stages of corrosion (Figure 2). This can raise concerns about how effective is encapsulation of the radioactive waste in grout, since waste mobility is not guaranteed using this specific treatment method. Containment's complete failure as expressed by steel fracture has been avoided in all the scenarios being investigated regarding the properties and the geometry of the encapsulated material.

Significant distortion may occur at relatively high corrosion extent based on the location of the metals inside the drum, albeit not enough to cause steel rupture. Accelerated corrosion tests have been also performed in miniaturised ILW-simulant drums as part of a more realistic approach to evaluate the system's behaviour.

The Impact

FEM and XRT were adopted to shed some light on the behaviour of ILW drums as the encapsulated metallic fragments corrode progressively. The results showed that the solid intact grout—waste matrix is vulnerable to the corrosion—induced volume expansion.

Even if the steel containment seems secure under the specific set up used for FEM and XRT, which is in favour of safety, grout cracking can be a potential threat for the ultimate disposal of the ILW drums. Hydrogen evolution upon reaction of uranium and magnesium with water as well as uranium corrosion products are known to be flammable in presence of oxygen. Therefore, a damaged grout core can create paths where air may contact the corrosion products causing pyrophoric events.

SOUTH WEST NUCLEAR HUB

University of BRISTOL