SOUTH WEST NUCLEAR HUB

Improving Life Assessment Procedure for Current and Future Generation Nuclear Power Plants

Research area: Structural Engineering

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The Challenge

Materials in nuclear power plants operate in extreme conditions (high temperatures and stresses) over lifespans that extend for many decades. The current generation of advanced gas cooled reactor plants have been in service for more than 40 years and the new generation of pressurised water reactor plants are expected to be operational for 100 years. To ensure their safe and long-term operation we need to understand how high temperature deformation and failure occurs under complex loading conditions, over these timescales. Current lab testing is typically limited to a handful of years at most and not always capable of providing the requisite insight into the microscale deformation of materials. We therefore need to support short term lab data with improved fundamental understanding of the micro-mechanical processes at play and develop sophisticated simulation tools.

The Solutions

To improve our fundamental understanding, we went to the Diamond Light Source in Oxfordshire, which is the UK's national synchrotron facility. The facility uses electrons, accelerated to near the speed of light, to produce light that is billions of times brighter than the sun. We used this facility and our custom built high-temperature stress rig to study high temperature deformation and plasticity at a microscopic level, watching how crystallites within the bulk solid responded to applied loading over time.

Figure 1

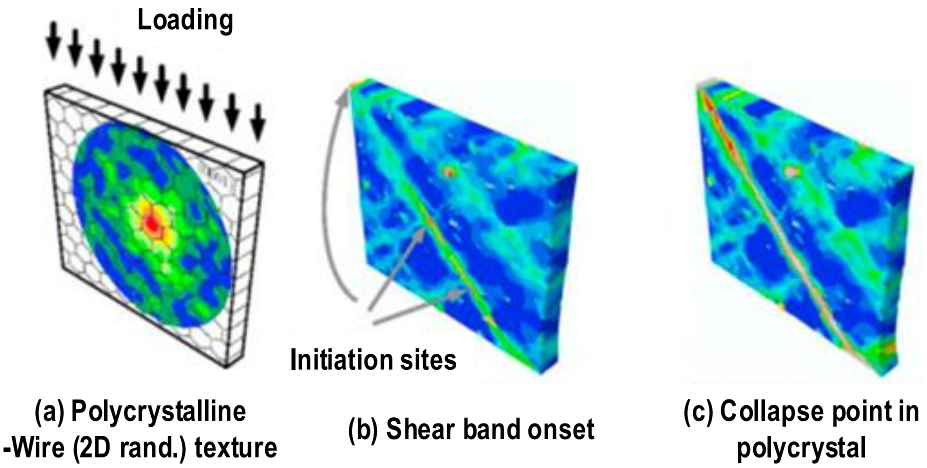
The Diamond Light Source

(Source: Diamond Light Source)

University of BRISTOL

Using the findings from this experiment, we were able to begin to piece together a detailed, fundamental understanding of the micro-mechanical deformation behaviour and feed this into novel crystal-plasticity models. These models can represent microscale material anisotropy and predict the response under the type of extreme conditions seen in nuclear plants.

Figure 2



Predicting damage development and plastic collapse using a novel crystal plasticity model (Zhang et al. 2016).

The Impact

EDF Energy plan on using the results from this project to inform their structural integrity assessments and improve life assessment procedures, such as R5 and R6. In the long run, improving the assessment procedure will enable the safe life extension of nuclear plants; with each of EDF's reactors generating around £700K worth of electricity per day. These life extensions represent a major contribution to the UK economy, jobs and security of energy supply. Moreover, the models developed in this project and the underlying methodology and tools can be applied across a wide range of engineering sectors, such as aerospace, automotive and petrochemical industries, where high-temperature deformation of metallic materials is of key importance.