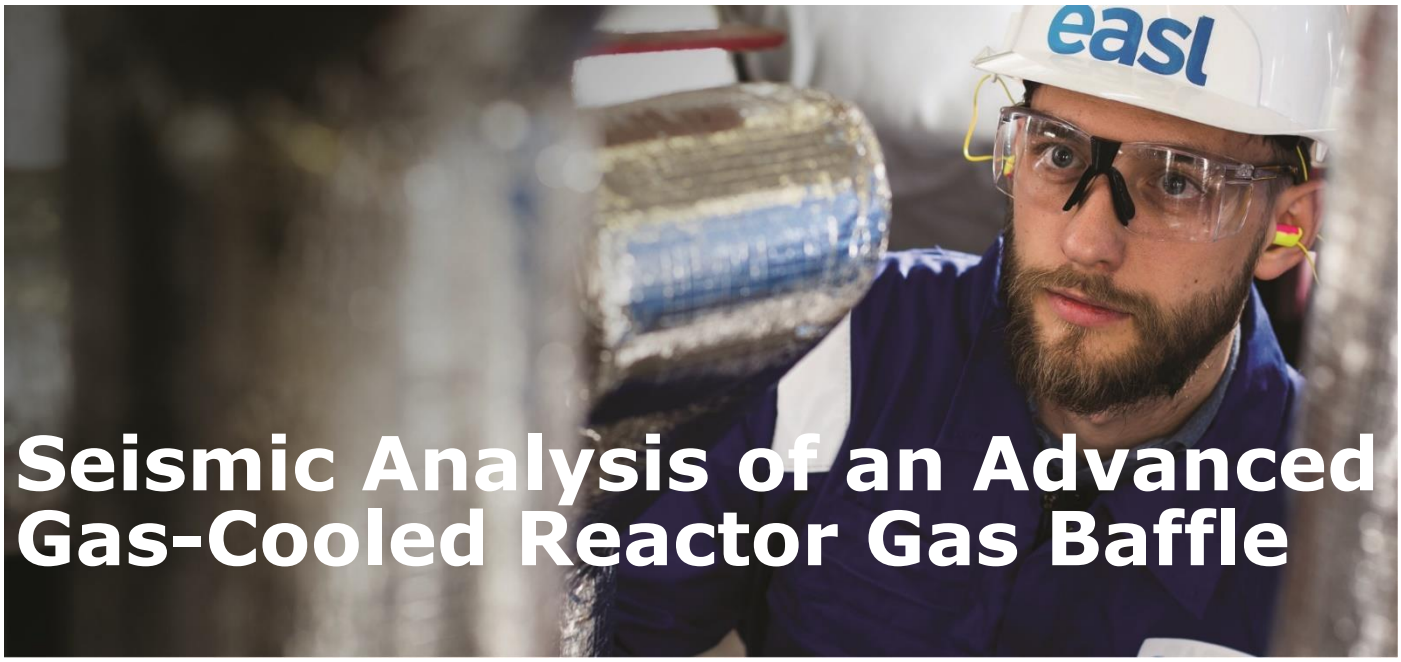

Seismic Analysis of an Advanced Gas-Cooled Reactor Gas Baffle

Case study

As a result of a periodic safety review of an advanced gas-cooled reactor (AGR) gas baffle safety case, a requirement was identified for establishing structural integrity in the gas baffle and circulator outlet gas duct (COGD) under a reference earthquake with a zero period acceleration of 0.14g corresponding to an annual probability of exceedance of 10^{-4}. EASL undertook a fracture mechanics assessment and an ASME III design code assessment of the critical components under pressure, temperature, static/dynamic mechanical loads and seismic loading. The stresses and strains obtained from this study were subsequently used to demonstrate that the AGR gas baffle design was fit-for-purpose when subject to the reference earthquake.

Our approach

The gas baffle and COGD form the pressure boundary around the reactor core: to direct coolant gas flow from the circulators through the reactor core, to house the reactor internal components and to facilitate access to the fuel and control rod assemblies.

Based on cost-effectiveness considerations, inelastic static analysis, response spectrum analysis and direct integration non-linear time history analysis methods using ABAQUS were carried out. These analyses included various inelastic material models to satisfy different assessment purposes.

The potential effects of some plasticity in the load paths on the dynamic responses obtained under linear assumptions were considered. The inelastic material models were tuned for the expected plastic strains in various regions to avoid overly pessimistic strain prediction.

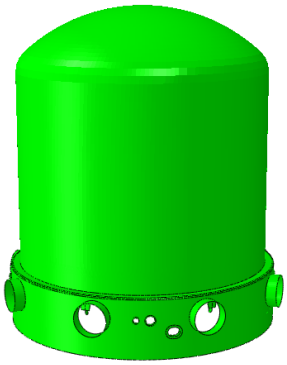

Figure 1 Global model of gas baffle and COGD

Different sets of seismic motions were applied to the dual support locations: displacement time histories representing the core/ diagrid seismic motion at the support webs and the floor acceleration time histories at the COGD anchor ring, together with the static displacements due to differential thermal expansion. The application of the prescribed boundary conditions was met with the limits in the facilities available in ABAQUS and this was resolved by substantial pre-processing.

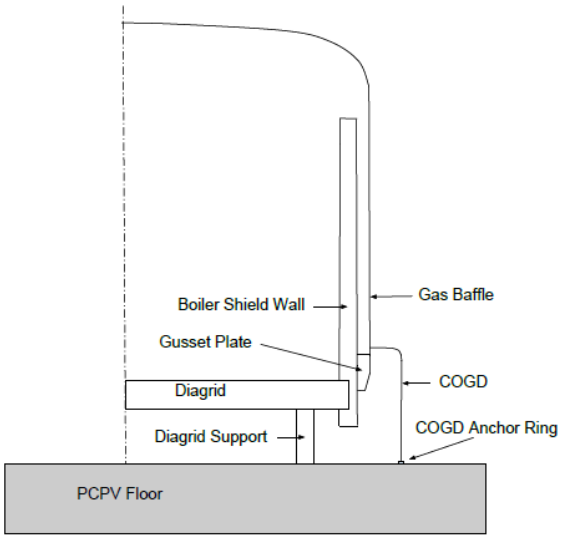

Figure 2 Gas baffle and COGD load paths

The stresses and cyclic strains (inelastic) obtained from this study were subsequently used in successful fracture and ASME III design code assessments including an accumulative strain check for the high-strain low-cycle fatigue failure mode.

Results

Standard validation exercises were carried out to underpin the confidence in the modelling and analysis. Horizontal acceleration time histories at selected locations from the analyses with linear elastic and inelastic local material properties were compared to demonstrate that no natural frequency shifts were present. This supports the use of a linear elastic model to obtain stresses for a number of the assessment load cases. In the vertical direction, the comparison confirms that the major global responses were the same, although unexpected high frequency accelerations were observed. Further interrogation proved that the high frequency contents were numerically introduced when the applied displacement history was converted into acceleration history internally by the FE solution process and therefore were not realistic.

As the gusset plates and castellations were primarily subjected to large reversal cyclic displacement loading over the period of seismic strong motion of no more than 20 seconds, and the pressure and temperature loads were small, no large membrane stress was expected. Therefore, the main concerns for these components were the strain limit and low cycle fatigue issues. The predicted maximum equivalent plastic strain (cyclic) in the gusset plates and castellations was found to be acceptable within the ASME III NB strain limits.

Conclusions

The study showed that the objectives for the FE modelling and analysis were heavily dependent on the assessment strategy. Recognising the limitation in the capability of the material models readily available in the commercial FE analysis software, substantial engineering appraisal and validation are required to provide the high confidence required for the client's safety case.

Other applications

The complex technical challenges on this task were met within the tight timescales specified. EASL demonstrated that the AGR gas baffle design was fit-for-purpose when subject to the reference earthquake thus resolving the concern raised in the client's periodic safety review.

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.

engineering analysis services ltd.
2 Edward Court, George Richards Way, Altrincham, WA14 5GL
0161 923 0070 www.easl-stress.co.uk