AGR Gas Baffle Fragment and Fuelling Guide Tube Impact Analysis

Antony M Hurst

Engineering Analysis Services Limited (EASL)
Altrincham, Cheshire, WA14 5GL, UK
+44 (0)161 923 0070, www.easl-stress.co.uk

Email: enquiries@easl-stress.co.uk

Abstract

The UK advanced gas cooled reactors use a graphite core with carbon dioxide gas as the primary coolant. There is a diaphragm above the core which separates re-entrant gas at lower temperature and higher pressure from that leaving the channel guide tubes at reactor outlet temperature. This diaphragm is known as the hot box dome. The dome is perforated to facilitate the passage of fuel and control rods into the core. The dome is fabricated in carbon-manganese steel and incorporates a number of separate plates joined together by full penetration welds which are post-weld heat treated.

Since dome failure could conceivably result in gas by-passing and, hence, failing to adequately cool the core the original safety case claims that gross failure of the dome is incredible. More recently potential failure modes of the dome have been reviewed and various dome weld failure scenarios analysed and assessed to demonstrate a tolerance to the consequences of complete failure of certain welds.

One of the largest of these welds is the cap plate circumferential weld. In this assessment instantaneous and complete failure of this weld was postulated, following which the dome cap fragment including attached fuelling and control rod guide tubes would accelerate upwards under the action of the net differential pressure. The fragment would move upwards until the top of the fuelling guide tube end ring impacts on a raised feature in the standpipe top bearing housing. The impact event was analysed using ABAQUS/Explicit [1] and the results from the analysis were assessed to determine the extent of deformation of the guide tube.

To underwrite the analysis techniques, analyses was carried out to reproduce the mean dynamic buckling plastic collapse loads of cylindrical test pieces reported in [2]. Good correlation was obtained with the test and analysis results, confirming a sound understanding of the analysis techniques.

Analysis of the population of guide tubes within the cap plate region for any reactor shows significant variation in the free travels i.e. the distance from the top of the guide tube to the impact site on the standpipe. That means the guide tubes would not impact at the same time, instead, when the first guide tube impacts the last one would still have some distance to travel before it would impact and so not all guide tubes will be effective initially. A methodology to account for this in the impact assessment was developed.

The fragment is predicted to reach a velocity just prior to the first impact of ~6 m/s and the fragment was predicted to come to rest in less than 50mm following the first guide tube impact. Including the “hot” free travel prior to first impact, the total predicted fragment travel is ~250mm. It was shown that buckling of the guide tube would occur in a thin section of spiral welded tube and the overall level of deformation is insufficient even to result in the formation of one convolution in the worst affected guide tube. Thus there is no adverse effect on the flow passage though the fueling guide tubes.

It may have been expected that deformation would be sufficient to “wedge” the guide tube into the top bearing housing. However the analyses indicated that after the initial impact the guide tube rebounds and the fragment falls, and hence this wedging effect would not occur.

The total predicted displacement of the fragment was used to calculate the core by-passing gas flow, the reduction in core cooling gas flow and resulting temperatures. Ultimately the peak fuel temperatures were shown to remain below a level at which widespread fuel clad failure would occur.

Keywords: **Impact analysis, numerical simulation, advanced gas cooled reactor, hot box dome.**

References

[1] ABAQUS, Finite Element Software, Version 6.9-1, Dassault Systemes, 2009.
[2] W Abramowicz and N Jones, Dynamic Progressive Buckling of Circular and Square Tubes, International Journal of Impact Engineering Volume 4, No 4, pp. 243-270, 1986.