Seismic Analysis of a Pressurised Water Reactor Insulation System (PWR)

Darchem Engineering requested Wilde to provide seismic qualification of an insulation system to be installed around a nuclear Reactor Pressure Vessel (RPV) of a Pressurised Water Reactor (PWR). The system had to remain fully functional, following the Design Base Earthquake (DBE).

Company

Darchem operates four business units; three provide engineered solutions for high temperature problems mainly relating to the aerospace industry. The fourth provides fire protection and high temperature insulation solutions for the offshore and nuclear markets.

The business unit that commissioned the Seismic Analysis project to Wilde was Darchem Insulations Systems, who are a world leader in the design and manufacture of lightweight engineered thermal insulation systems.

Darchem deal with some of the world's leading companies, including the following:

- Siemens
- BAE Systems
- McLaren
- Boeing
- Goodrich
- Airbus
- Rolls Royce
- Shell
- BP
- Bombardier

Background

A Pressurised Water Reactor (PWR) is used in the majority of western nuclear power plants. In a PWR the primary coolant, superheated water, is pumped under high pressure to the reactor core, then the heated water transfers thermal energy to a steam generator.

The Reactor Pressure Vessel (RPV) is a vessel containing the coolant and reactor core and is a device for containing and controlling chemical reactions. The chemical process enables conversion of raw material into the final product under given pressure and temperature. During the reaction it becomes necessary to remove excess heat to keep the process stable. Pressure vessels are built to withstand the high pressures in the system.

Design Base Earthquake (DBE) ground motions for nuclear installations are established to provide design input information to be used in nuclear safety studies. Reactors should be built and operated to pose no undue risk to public health and safety from earthquakes and other hazards.

> “” Everything about **Wilde FEA exuded first class quality** from the moment John Dennis came to visit us to **listen to our requirements**.

Challenge

Darchem Engineering requested Wilde to provide seismic qualification of an insulation system to be installed around a nuclear Reactor Pressure Vessel (RPV) of a Pressurised Water Reactor (PWR). The system had to remain fully functional, following the Design Base Earthquake (DBE).

Solution

The project was headed by Wilde Analysis Technical Director, John Dennis. John has extensive experience of the requirements of the nuclear sector, having previously worked for the National Nuclear Corporation Ltd. He has more than 25 years of experience in the field of FEA (Finite Element Analysis).

Much of the structure was relatively thin-walled when compared to the main dimensions, and therefore it was decided that shell elements would provide better accuracy/solver time performance than meshing the geometry directly with solid elements. Consequently, significant mid-surface generation was performed using **ANSYS DesignModeler** to prepare the CAD geometry appropriately.

An FEA model was then developed in sufficient detail to predict the dynamic behaviour of the insulation system. A modal analysis was performed to establish the significant modes of vibration of the structure. These were compared with the input loading spectra to establish appropriate acceleration levels to be applied to the system.

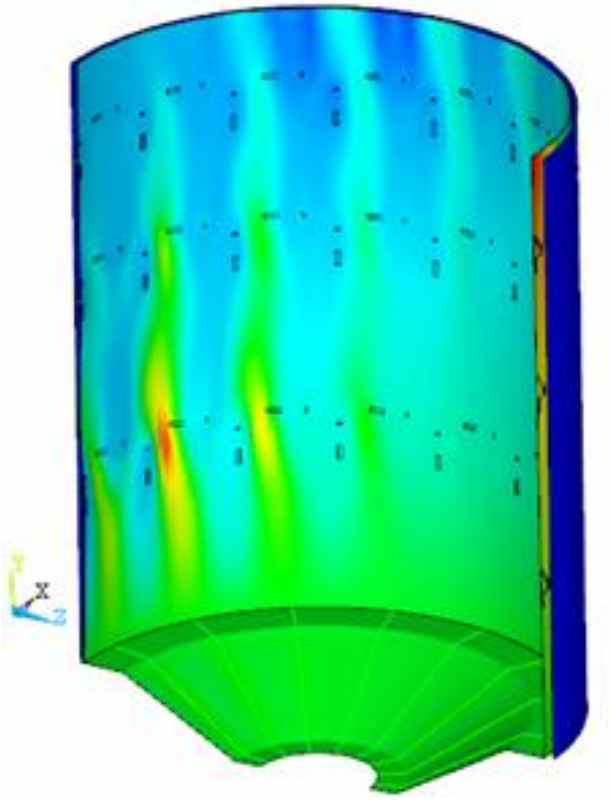

Fig 1: Seismic qualification of insulation system for PWR nuclear reactor (Courtesy: Darchem Engineering Ltd)

Pseudo-static seismic analysis was then carried out for each loading direction. The individual direction results were combined with the effects of other loading conditions. Stress results were compared against the appropriate allowable values. Displacement values were checked to ensure continued functionality of the system post-earthquake.

Finally, a technical report was supplied as part of the overall design package. The plot in Figure 1 below shows displacements of the insulation shell.

Business Benefits

The nuclear insulation system is an inherent part in the continued safe running of the nuclear reactor. It is highly inaccessible during its service life and there must be clear evidence to indicate the robustness of the unit before installation is considered.

Although shake table testing could be performed on this structure to check its performance under seismic conditions, FEA provides a greater insight into structural behaviour, and is more economical than the physical testing alternative.

> “ **Wilde's extensive experience** provided Darchem with advice on the **most cost- and time-effective options** available for the analysis, whilst retaining **accurate and robust results**. The final report, results and the time scale in which this was achieved, **further confirmed Wilde's quality of service**.