DBB Vessel Preliminary Design Support

Case study

The Mega Amp Spherical Tokamak (MAST) facility at Culham Centre for Fusion Energy is undergoing a major upgrade (MAST-UE) that will enhance the UK's role in international fusion research. A new double beam box (DBB) vessel which houses the two Positive Ion Neutral Injectors (PINIs) is required for the upgrade. This vessel needs to meet the following criteria:

- **The vessel must be designed to recognise ASME or European pressure vessel code as far as practicable.**
- **The vessel must be ultra-high vacuum compatible.**
- **Mounting points must be achieved with a high degree of positioning accuracy and allow for adjustment.**
- **Deflection must be minimised when under a vacuum.**

EASL was tasked with assessing the new DBB design to ensure it meets the above criteria, to ensure it is compatible for manufacture and to ensure it meets inspection/welding design code requirements.

Our approach

The task was separated into two phases with each containing a manufacturability analysis and a structural analysis.

EASL have extensive experience of using UK and international standards to conduct design code assessment.

A finite element analysis (FEA) model was used to determine the normal operating and fault stresses and the stress variations due to cyclic changes in pressure. EASL were able to simplify many loading scenarios into bounding cases to provide all the required results as quickly and cost-effectively as possible.

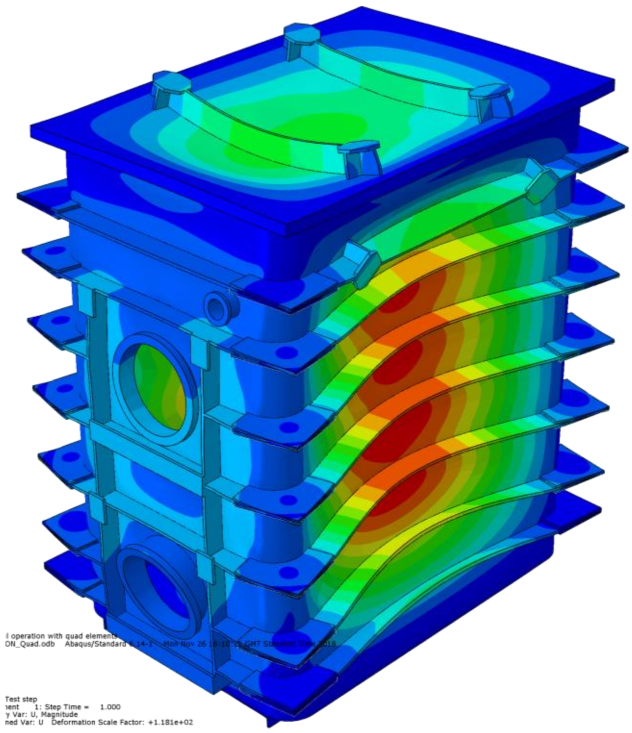

Figure 1 Exaggerated deflection under vacuum loading.

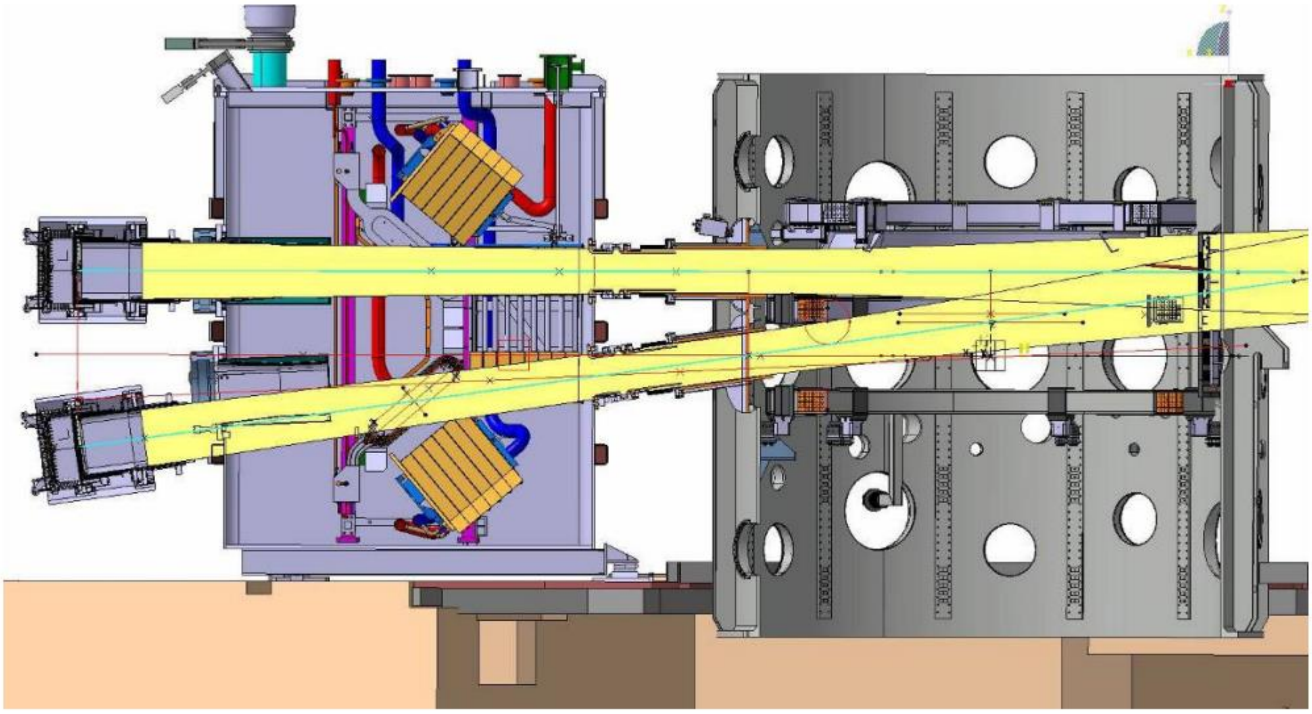

Figure 2 DBB Vessel with PINIs attached to MAST Vessel – Courtesy of UKAEA.

A linear, elastic FEA was run first, with a focus on finding areas with the potential for gross plastic deformation. To ensure the model is accurate, areas of interest were refined and necessary weld details were modelled. Carefully modelling the minimum detail necessary reduced the cost to the client and the lead time.

Using non-linear FEA to determine the limit analysis collapse load for the DBB vessel, EASL were able to demonstrate safe margins against plastic collapse even under the bounding fault conditions.

Using data from the linear, elastic FEA model areas were grouped together based on similarity of the features to facilitate efficient assessment of code compliance for the parent material and welds.

Various modifications to the design were recommended by EASL and implemented by the client after the first phase. This allowed for the complexity of manufacturing to be significantly reduced without compromising the client's requirements.

Weld detailing was specified to ensure sufficient strength while minimising expected welding distortion. Research into new areas to minimise this distortion, such as vibratory stress relief, was critical to ensure the final vessel met the tight design tolerances.

Assembly order was also carefully defined to simplify manufacture, reduce distortion and improve inspectability.

Expert design advice

EASL's suggested improvements were warmly welcomed by our clients.

If you would like to find out how EASL can help solve your vessel design and manufacturing issues, please get in touch with our experts.

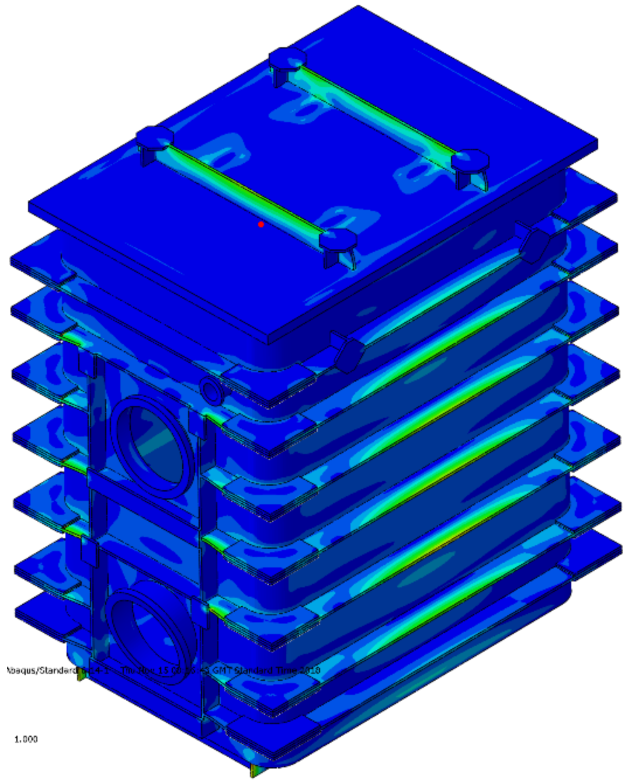

Figure 3 Modified final model.

engineering analysis services ltd.

2 Edward Court, George Richards Way, Altrincham, WA14 5GL

0161 923 0070 www.easl-stress.co.uk

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