Understanding Design Philosophy and Imposed Temperature Limits

Case study

During 2016 a challenge to existing operational temperature limits of an internal skirt led to a temporary derating of the associated nuclear reactor. To better understand the consequences of exceeding temperature limits and to avoid future, costly deratings, EASL were selected to investigate the basis for the existing limits and advise on the structural integrity consequences of temperature gradients within the skirt.

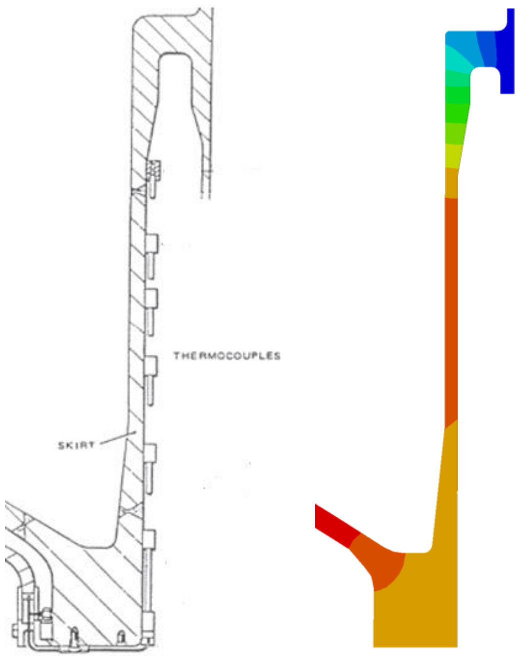
Our approach

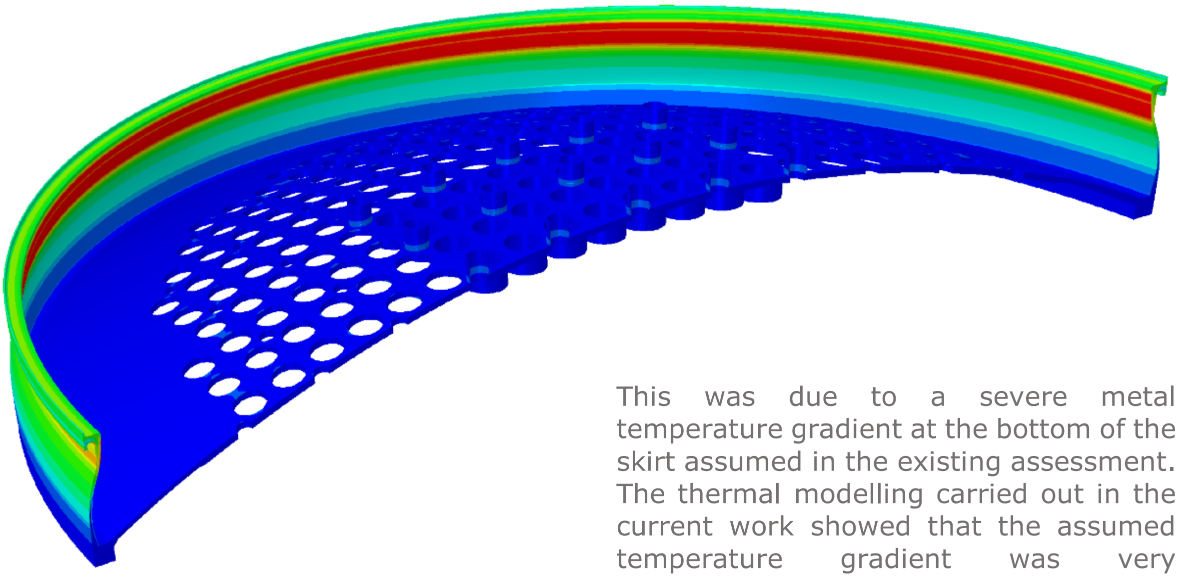
The EASL approach to the challenge began with a review of existing literature and assessments concerning temperature limits and the effects of thermal stresses in the skirt. This provided a sound understanding of the types of structural integrity threats faced by the skirt and the general ideas behind some of the temperature limits.

It was clear that thermal effects posed a threat in terms of defect tolerance and fatigue life. The thermal stresses were sufficiently short range to rule out any effect on plastic collapse. It was also established that creep would not pose a significant threat.

In order to explore the full range of temperature limits and to quantify the effects of the resulting temperature gradients it was agreed that further temperature and stress modelling should be carried out and an existing finite element model was adapted for the purpose.

Vertical and circumferential temperature distributions were designed in consultation with the client to maximise the structural integrity challenge posed to the skirt whilst respecting some or all of the existing temperature limits.





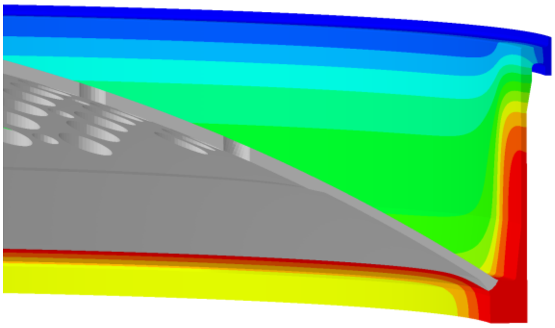
The mechanism by which severe temperature gradients could arise in the skirt was considered and it was decided the most realistic cause is hot gas entering into an annulus surrounding the skirt. The desired temperature distributions were therefore modelled assuming convective heat transfer, with the gas temperature tuned to meet the specified temperature distributions.

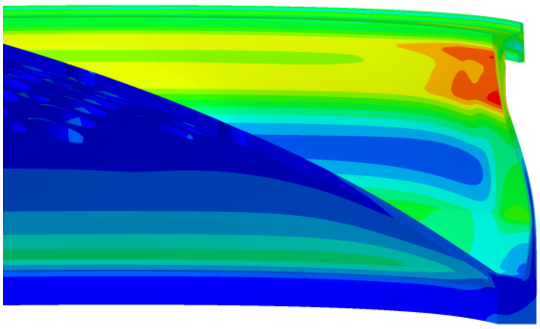
The result

For the hottest of the temperature distributions it was shown that approaching temperature limits at the very top of the skirt on a regular basis could result in significant additional fatigue damage. However, it was also shown that approaching this temperature limit as a result of hot gas entry into the annulus was not feasible without breaching temperature limits lower down the skirt. Further, the effect of a sharp temperature gradient at the top of the skirt was not readily distinguishable from that of a hot skirt in general. Based on this work the temperature limits at the very top of the skirt were shown to be of limited benefit while those slightly lower down were shown to play a key role in limiting stress at the top of the skirt.

Some of the modelled temperature distributions resulted in reduced defect tolerance at some locations, however the overall bounding case from existing assessments remained bounding.

This was due to a severe metal temperature gradient at the bottom of the skirt assumed in the existing assessment. The thermal modelling carried out in the current work showed that the assumed temperature gradient was very pessimistic compared to what might arise in reality, even when a very cold annulus gas temperature is assumed.





The EASL investigation and analysis provided an enhanced understanding of the existing temperature limits and served to clarify the threats to structural integrity of the dome skirt. In particular, the work provided substantial reassurance in respect of fast fracture, this being the overriding integrity concern for the skirt.

If you'd like to know more, please contact us or take a look at our website.

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