TRANSIENT THERMAL STRESS ANALYSIS OF A SPHERICALLY CURVED TUBESHEET

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Currently, a concept of double-wall-pipe type steam generator (SG) is being introduced and investigated as an innovative technology to realize next-generation sodium-cooled Fast Breeder Reactor (FBR). Under the Japanese national policy, the preliminary conceptual design of the demonstration reactor must be decided by 2015, which leaves little time for broad considerations.

The new concept of the SG is posing great challenges in the engineering design of a tubesheet bundling over 7000 double-wall pipes. In order to withstand the steam pressure and to reduce the thermal strains across the thickness of the sheet, the structure is shaped in a spherically curved fashion, which is completely different from the traditional concept of implementing a flat sheet.

Currently, no design-by-analysis methods exist for spherically curved tubesheets because it is a new concept. Assessment by the traditional design methods and criteria yields tremendously large stress. In order to design a feasible tubesheet, areas of high stress and its magnitude must be predicted and identified. Furthermore, mechanisms behind high stress concentrations must be unveiled.

At CCSE, JAEA, large-scale numerical simulation methodologies and software are developed to solve this problem. A new notion of assembly structure analysis within a Grid computing environment is proposed and a finite element structural analysis software called FIESTA was designed and implemented based on this method.

It is currently estimated that over 10 million degrees of freedom are necessary to accurately predict the deformation state of the tubesheet, which makes data construction a costly process, if not impossible. By implementing the notion of an assembly structure analysis, finite element mesh data construction can be carried out in a part-wise fashion. The FIESTA solver is able to ‘glue’ those data made independent of one another using a penalty.

Since the introduction of a penalty degrades the condition of the global stiffness matrix, the effect of the parameter on the convergence of the conjugate gradient solver was investigated through a simple sample problem. It was witnessed that as the size of the penalty exceeds the elastic modulus, the rate of increase in the procedure time accelerates. Therefore, there is a trade-off between computational time and accuracy, which must be decided at the time of simulation.

Using FIESTA, it is anticipated that a feasible design will be developed for the new-concept tubesheet structure. In the near future, it is expected to complement the experiments to establish a new design-by-analysis method for the spherically curved tubesheets in FBRs.