§4. Finite Element Method Analyses of Thermal and Irradiation Creep Behavior of FFHR Blanket

Yamamoto, T., Matsui, H., Fukumoto, K. (Inst. Material Res., Tohoku Univ.)

In order to assess engineering feasibility of the self-cooling molten-salt blanket system of FFHR, it is required to optimize the design details examining temperature and stress field over the blanket structure. The objective of this study is to estimate temperature and stress field in the blanket structure of the currently optimized design under the operation.

Figure 1 shows the analysis model obtained through a couple of modifications made to the original one in the following points. The flibe flow in each unit was divided into two streams. The first one goes just beneath the first wall with efficiently relieving the thermal load of the wall surface, while the second one goes through the Be pebble bed. The first wall was modified to have round shape to avoid the stress concentration at the corners. Several slits were introduced to the thermal and radiation shielding to suppress thermo-mechanical deformation caused by a large temperature difference between the top and the bottom of it. The structure is made of V-4Cr-4Ti alloy and the first wall is 5mm thick.

Thermal creep and irradiation creep analyses of the model have been performed using the finite element method analysis code, ABAQUS. Thermal creep behaviors of the alloy under various stresses at various temperatures were obtained from activation energy, Qc, of 115kcal/mol that has been determined experimentally for V-4Cr-4Ti-0.1Si alloy and the stress exponent, n, of 10 - the typical value for vanadium alloys. The irradiation creep behavior was modeled based on the data obtained by Troyanov and Smith et al.

In the thermal creep analysis the boundary conditions were changed in the following sequence. Flibe flow pressure is loaded at 450°C (step 0), heat flux is loaded to the operating condition (step 1), the conditions are kept for 30 days (step 2) and the coolant is cooled down to the initial temperature (step 3). Heat flux from plasma and average flow rate are is 0.25MW/m^2 and 0.3m/s, respectively. In the irradiation creep analysis, irradiation creep behavior was additionally considered in the step 2.

The maximum temperature and pressure were 600°C and 20 MPa, respectively, at the beginning of the operation. No deformation was observed after 30-day operation in thermal creep analysis because thermal creep rate is as low as 10^{-17} (h^{-1}) under that condition. In the irradiation creep analysis significant stress relief was observed after the operation as shown in Fig.2. This causes residual stresses in the counter directions. However the maximum residual stress is only 15MPa and is considered to have no effect on structural integrity. It is still necessary to examine the stress field under severer loads (larger heat flux, larger temperature change or higher coolant pressure) or the longer-term and/or cyclic operation.

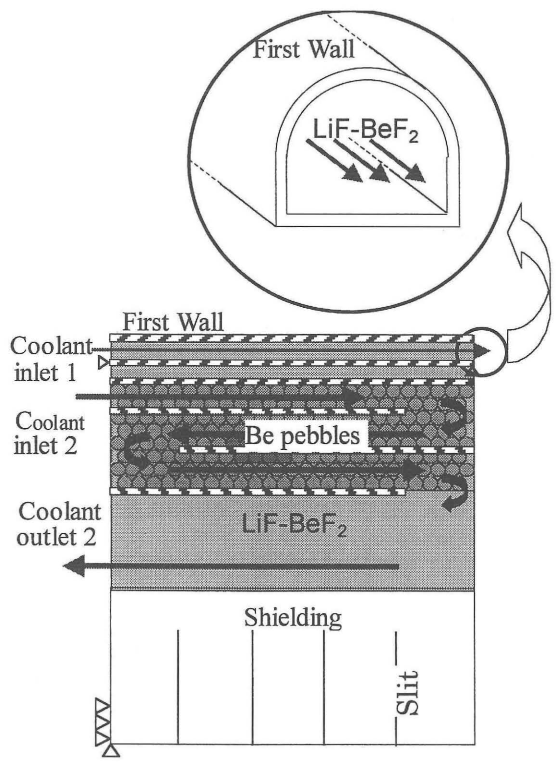

Fig.1 Structure of the analysis model

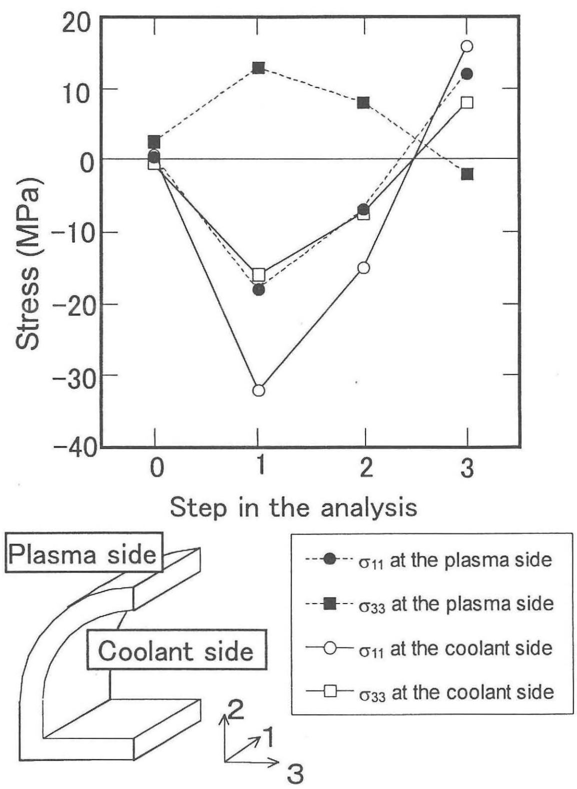

Fig.2 Stress histories at the plasma and coolant sides of the first wall in the irradiation creep analysis.
Step 0 - only the coolant pressure is loaded,
Step 1 – heated flux is loaded,
Step 2 – after the operation for 30 days,
Step 3 – cooled down to the initial temperature.