§4. Thermal and Structural Analysis of FFHR Blanket

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Optimization of the molten salt blanket structure of FFHR based on the numerical thermal and mechanical analysis is important in order to assess the engineering feasibility of the reactor concept. In the present study, flow analysis of coolant/breeder Flibe using α-FLOW, and thermo-mechanical analysis of the fusion first wall using ABAQUS code has been performed. Temperature and stress distribution within the first wall structure material under reactor operation have been obtained, and optimization of the structure has been attempted.

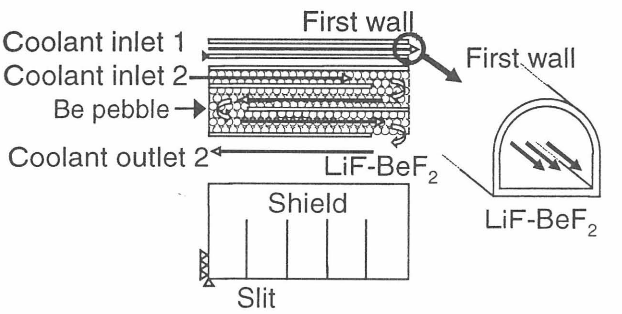

Fig. 1. Structure of the blanket used in the analysis.

In the blanket of FFHR, beryllium pebble has been adopted as neutron multiplier as well as a material to control the REDOX potential of the coolant/breeder Flibe. Based on the original conceptual design, an improved version of the model where stress and temperature has been reduced is given in Fig.1. In order to reduce the stress concentration on the corner due to the internal pressure, the cross section of the first wall structure has a semi-circular shape. There are two series of coolant channels, and the channel close to the plasma side is mainly for heat removal. Plasma side channel and shielding block are separated in order to reduce thermal stress, and slits are made in the shielding block to further reduce thermal stress. From thermal analysis within the coolant, it became clear that the heat from the first wall is not well transferred to the entire flibe flow but the heat is carried only by the circumferential flibe flow due to its poor thermal conductivity. It is therefore necessary to further optimize the design in terms of the heat removal characteristics.

Figure 2 shows the relation between the wall thickness and resulting thermal stress. The sum of thermal stress and stress arising from internal pressure shows a minimum in this plot (gray symbols), and the wall thickness corresponding to this minimum is about 5mm, which is considered optimum in this

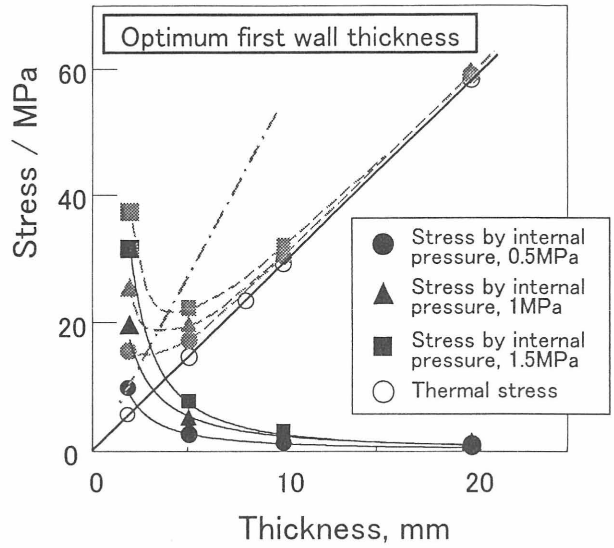

Fig. 2: Stress vs. the first wall thickness

design configuration. Figure 3 shows the estimated temperature of the first wall under higher heat flux conditions from the plasma, aiming at higher performance anticipated in the future. It is possible to increase the heat flux up to 0.25MW/m^2 in the present design adopting V-4Cr-4Ti as the structural material, for which the design allowable temperature limit is 750°C.

As a result of design optimization, the optimum thickness of the first wall has been determined as 5mm, which enables to reduce the first wall temperature to 600°C and the stress below 20Mpa under the condition of the plasma heat flux of 0.1MW/m^2 and the average coolant flow velocity in the plasma side channel of 0.3m/s. In the current design configuration, plasma heat flux may be increased up to 0.25MW/m^2. It is expected that further increase of the plasma heat flux may be possible by enhancing the heat transfer efficiency by adopting 3-dimensional coolant flow for Flibe.

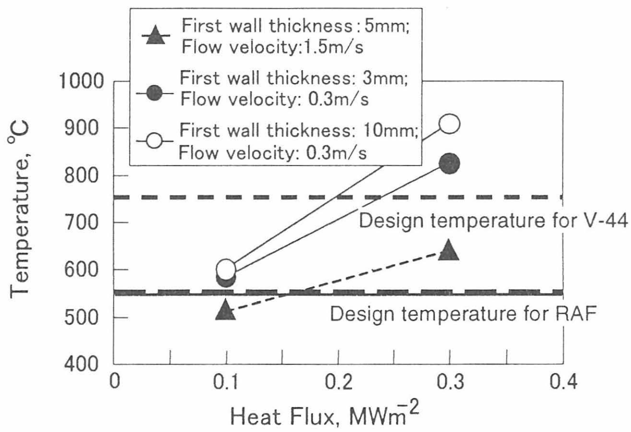

Fig. 3, Temperature of the first wall under heat flux from the plasma