§29. Optimized Thermo-mechanical Design of High Intensity Neutron Source Test Cell for Material Irradiation

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The International Fusion Materials Irradiation Facility (IFMIF) project has been moved vigorously forward for material development of fusion reactors. Authors have been involved in a design activity of the high flux test module (HFTM) of IFMIF. We have proposed a HFTM design which could accommodate wide temperature range at irradiation test and make it possible to control temperature of irradiated specimens precisely, and have examined the design by conducting thermalhydraulic experiments and numerical simulations. The previous experiments and simulations, however, focused on a part of HFTM such as the irradiated volume, the upstream of the irradiated volume or one of nine capsule installed in the irradiated volume. In this study, we focus not only on the part but on the whole HFTM based on our concept and verify its consistency.

In our design of HFTM, capsules housing irradiated specimens are elongated in the spanwise direction according to the beam-footprint. The elongated capsule promotes uniform temperature distribution in it, and consequently makes the temperature control simple. We can draw up plans for HFTM but it is just a draft without actual fabrication. In order to spot some problems which are difficult to become apparent from the draft, we fabricate a full scale model of the HFTM based on our design. Fig. 1 shows a photograph of the full scale model. As a result, it is confirmed that no obvious structural problem arise from the present design building up and breaking down the module and when drawing thermocouples or lead wire of heaters from capsules.

Our design of HFTM doesn't allow to use a kind of supporting plate to reinforce an irradiated rectangular vessel of the test module so as not to deform the vessel. Therefore, it is important to estimate the influence of gaseous coolant pressure on the vessel deformation. We investigate the influence by performing numerical simulation which combines structural analysis and turbulent heat transfer analysis, and elucidate the change in velocity distribution of coolant and its cooling performance due to the vessel deformation and the influence on temperature control of irradiated specimens. The vessel deformation caused by pressure difference between the inside and outside of the vessel is solved by using finite element method (FEM). The obtained vessel shape is given as a boundary condition to a large-eddy simulation formulated by FEM and turbulent heat transfer in the cooling channel is calculated. The cooling channel is enclosed by a flat wall of irradiated capsules and a deformed vessel wall. Its width before deformation is 1 mm and heat flux from the capsule wall is constant at 0.15W/m^2 assuming neutron flux distribution is spatially constant. When Reynolds number based on the channel width as a length scale and mean velocity as a velocity scale is 4560 and the deformation corresponds to the case that the vessel wall thickness is 1 mm and the pressure difference between the inside and outside of the vessel is 0.5 MPa, in this case the maximum deflection of 0.24 mm appears on the vessel wall, temperature rise in the center region of the capsule wall is seen for deformed case and this rise corresponds to 22 °C if the coolant is gaseous helium of 0.5 MPa with 50 °C at the inlet. The deformation using the present simulation is considered to the upper limit of the design and the temperature rise due to the vessel deformation generated in the actual HFTM is considered to be smaller than the present result. In addition, actual neutron flux has spatially large change and this causes large temperature difference in capsules. From this simulation, it is not the vessel deformation but the temperature difference in capsules that has a large influence on the cooling performance. It is rather important to scrutinize nuclear heat generation originating from the spatial distribution of the neutron flux.

We continue to develop the porous-type gas manifold which is used as a flow distributor of coolant entering an irradiation region of the module. In this study, punching metal plates are used in the experiment together with ceramic form as porous media to even spatial velocity change in the coolant. The previous experiment used only ceramic form and a certain level of uniform velocity profile was obtained. Using punching metal plates makes the profile more uniform and precise flow control can be achieved by the manifold.

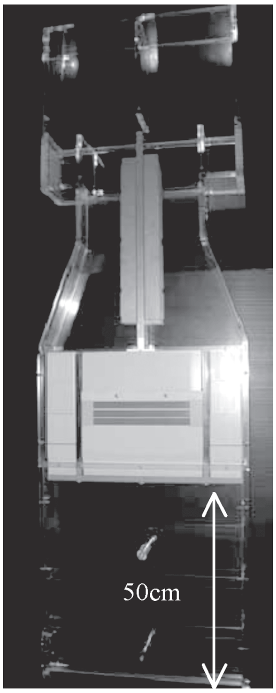

Fig. 1 a full scale model of HFTM