§8. Investigation of Radiation Shielding Performance of Metal Hydride Materials in FFHR-d1 Design

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Metal hydrides which contain high concentrations of hydrogen atoms have been candidate materials for a neutron moderator and shield in fission reactors and also in fusion reactors.[1,2] In the present study, applicability of hydride shielding materials are investigated for the design of FFHR-d1 focusing especially on consistency with the reactor structure.[3]

Comparison of shielding performance for fast neutrons of >0.1 MeV is shown in Fig. 1. The thicknesses of the Flibe cooled blanket and radiation shield have been optimized in our previous studies and the target of the fast neutron shielding is <~1 x 10^{10} n/cm^2/s at the backside of the shielding layer.[4] The FFHR-d1 design has been conducted by adopting a combination of ferritic steel and B_4C (FS+B_4C), and WC as stable and effective shielding materials. One-layered ZrH_2 and TiH_2 shields show superior performances compared with that of FS+B_4C and close to that of WC. In addition, the important feature is that performances of two-layered FS/ZrH_2 and FS/TiH_2 are almost the same to those of one-layered hydride shields at the backside of the radiation shield, although the attenuation of neutron flux (>0.1 MeV) in the first FS layer is inferior compared with the other shields. This is considered due to that the metal atoms, i.e. Fe, Cr and W in the ferritic steel, have inferior shielding performance for neutrons of lower than several MeV. In the second hydride layer, hydrogen atoms attenuate the low energy neutrons drastically by elastic scattering.

The above feature of the two-layered FS/ZrH_2 and FS/TiH_2 shields is significantly important to keep consistency with the helical reactor design. The proposed configuration of the two-layered shield is shown in Fig.2. The thickness of the vacuum vessel of the present helical reactor design is thin and considered impossible to support all the heavy in-vessel components such as blanket modules and divertors. Therefore, the in-vessel components must be supported by robust structures prepared in the radiation shield space between the core plasma and the vacuum vessel. By adopting the two-layered configuration, the 51 cm thick front FS layer can be used as robust helical structures to support the in-vessel components.

In addition, the hydride materials can be placed at the backside in the radiation shield space. Our experiments show that both ZrH_2 and TiH_2 start significant hydrogen dissociation at ~370 ^{o}C. This indicates that the temperature of the hydride materials should be controlled under ~300 ^{o}C in the vacuum vessel. Since the temperature of the blanket modules placed in front of the radiation shield will be higher than 500 ^{o}C, the front side of the radiation shield would be higher than 300 ^{o}C. Therefore, the backside of the shield space is a preferable position for the hydride shielding materials. To ensure the hydrogen retention during a long reactor operation of 30-40 years, a coolant gas should contain a low concentration of hydrogen. A replaceable configuration is required for the quick recovery in case of an accident.

In the present study, the applicability of ZrH_2 and TiH_2 has been investigated also for radiation shielding of out-vessel components such as heating and diagnostic systems.[3] The hydride materials show preferable performance in shielding for streaming neutrons emerging through divertor pumping ports and in neutron attenuation in the bending duct compared with the FS+B_4C and WC shields. Decay of radioactivities of ZrH_2 and TiH_2 after reactor shutdown is quicker than that of a ferritic steel and this might also be a reason to select the hydride materials especially for shielding of out-vessel components.

In parallel with the neutronics investigation, experimental studies on fabrication of shielding blocks by cold press of hydride powders and examination of their properties are being conducted.[5]

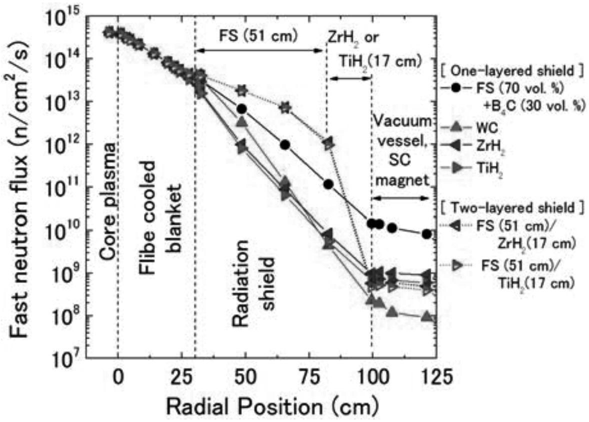

Fig. 1. Attenuation of fast neutron fluxes of >0.1 MeV in one-layered and two-layered shields.

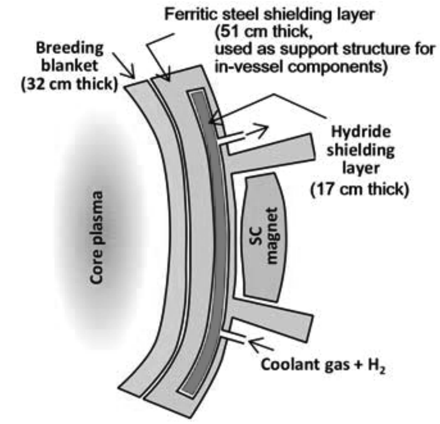

Fig. 2. Proposed configuration of a two-layered FS/hydride shield.

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3) Tanaka, T. et al. : accepted to Fusion Sci. Technol.
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