3-12 Compact Fusion Reactor Using Advanced Shield Materials

－Application of Hydrogen-Rich Hydride to the Shield of Fusion Reactor－

Table3-1 Hydrogen density of various materials

The anticipated hydrogen concentration of $Mg(BH_4)_2$, which is a new candidate shielding material, is as high as 1.32 x 10^{29} H-atoms/m^3, surpassing those of already known TiH_2 (9.1 x 10^{28} H-atoms/m^3), polyethylene and water.

Material	Appearance	Mass number	Density (10^3kg/m^3)	H density (10^{28}/m^3)
Mg $(BH_4)_2$	powder	53.99	1.48	13.2
TiH_2	powder	49.88	3.77	9.1
ZrH_2	powder	93.24	5.6	7.2
Polyethylene	Solid	14.03	0.90	7.7
H_2O	liquid	18.02	1.00	6.7

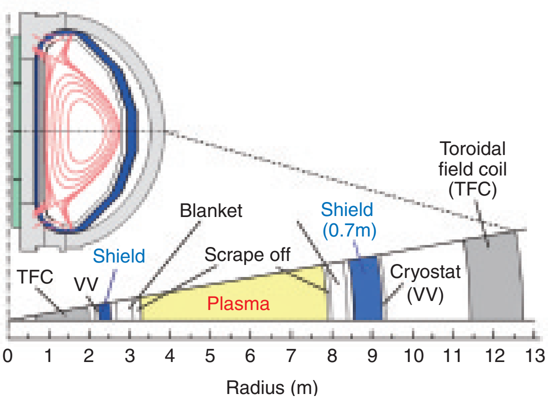

Fig.3-26 Cross section and 1-D calculation model of a low aspect ratio tokamak reactor

Neutron transport calculations of the 0.7 m-thick outboard shields were performed in order to evaluate the neutron shielding capability.

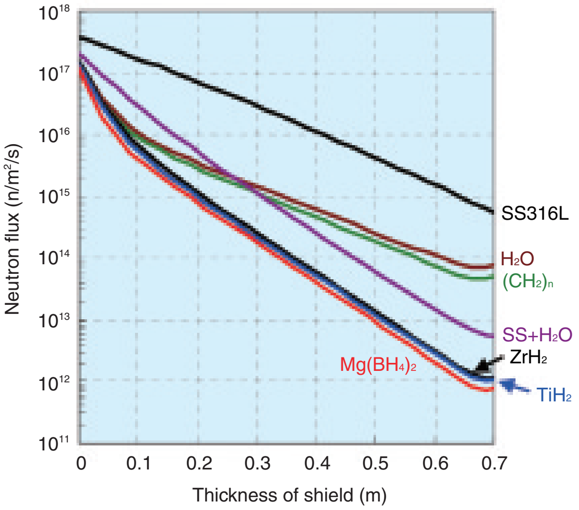

Fig.3-27 Attenuations of fast neutron fluxes in 0.7 m-thick shields made from various materials

The hydrogen-rich hydrides show superior neutron shielding capability compared to the conventional materials. Neutron transport calculations of the 0.7 m-thick outboard shields indicated that $Mg(BH_4)_2$, TiH_2 and ZrH_2 can reduce the thickness of the shield by 23%, 20% and 19%, respectively, compared to the combination of steel and water.

To demonstrate economical power generation with a compact reactor, the fusion DEMO studies at JAEA focus on a low aspect ratio (A) tokamak. It is important to reduce the nuclear heating caused by both neutron and gamma interactions in order to maintain the superconductive state of toroidal field coils (TFC); this is done with a compact neutron shield. Such an excellent shield also can be also used to protect outer structural materials from serious activation, and can lead to a dramatic reduction of radwaste.

This paper presents for the first time a new candidate neutron shielding material, magnesium borohydride ($Mg(BH_4)_2$), which is one of the most promising materials for storage of large amounts of hydrogen. Table3-1 gives several metal hydrides, borohydride and their properties. The anticipated hydrogen concentration of $Mg(BH_4)_2$ is as high as 13.2 × 10^{28} H-atoms/m^3. It is notable that some hydrides have considerably higher hydrogen content than polyethylene or water.

Neutronics calculations were carried out in order to assess the capability of $Mg(BH_4)_2$ and metal hydrides such as titanium hydride (TiH_2) and zirconium hydride (ZrH_2) which are candidates for the new shield material. Fig.3-26 shows the poloidal cross section and a 10° sector model of the low aspect ratio tokamak.

Fig.3-27 shows the calculated attenuation of fast neutron ($E>0.1$ MeV) flux in outboard shields made from various materials. The mixture of SS and H_2O consisting of 70% stainless steel SS316L and 30% water, which is presently one of the main shielding materials in fusion device design such as ITER, also was calculated. The thickness of a shield of $Mg(BH_4)_2$, TiH_2 and ZrH_2 can be respectively 23%, 20%, and 19% less than the combination of SS and water. Also, though the γ-ray shielding capability of only $Mg(BH_4)_2$ is low, mixing $Mg(BH_4)_2$ with steel significantly improves gamma-ray shielding.

The hydrogen-rich hydrides exhibit superior neutron shielding capability. Neutron transport calculations of the 0.7 m-thick outboard shields indicate that some hydrides allow the shield to be more than 20% thinner than the combination of SS and water.

Reference

Hayashi, T. et al., Neutronics Assessment of Advanced Shield Materials using Metal Hydride and Borohydride for Fusion Reactors, Fusion Engineering and Design, vol.81, 2006, p.1285-1290.