Shielding Capability Simulation for Neutron and Gamma Rays Using Metal Hydride Materials

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1. Introduction

From the Chernobyl nuclear accident to the recent Fukushima nuclear accident, the problems related to radiation exposure occurred. The exposed radioactive materials pollute environment and cause serious damage when irradiated to electronic devices and human body. [1] Gamma rays are strong enough to penetrate a few centimeters of lead panel, making it thicker to shield. Neutron radiation should be shielded by providing high density concrete with a mixture of boron, cadmium and so on. There are problems such as human toxicity, environmental pollution caused by disposal, high manufacturing cost. [2] We should develop a new shielding material that complements the disadvantages of neutron and gamma ray shielding materials that have been used in the past. Our research have conducted to apply metal hydride as a shielding material because the heavy metal compounds with a lot of hydrogen contents seem the possibility of simultaneous shielding of neutron and gamma rays.

2. Experiment

In our study, we conducted computer simulation using MCNP6(Monte Carlo Neutron and Photon code6). The analytical model is a spherical model with a radius of 10 cm as shown in Fig. 1, and is designed to tally the flux from the outside with a dotted source of 10 Mev. Our researches on light metal hydride (B, Li, etc.) and high performance shielding materials (B, Be, Fe, Li, W, etc.) addition was carried out.

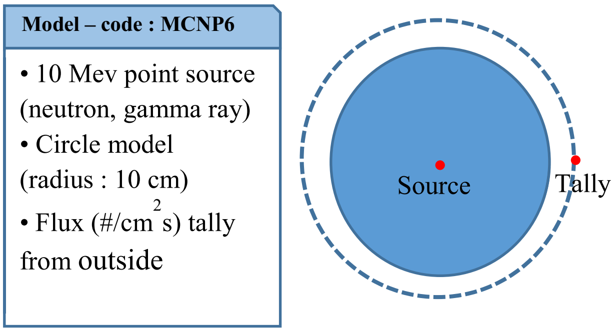

Fig. 1. MCNP6-based shielding capability analysis model design.

3. Results

In table 1, simulation results show that the metal hydride materials such as $LiAlH_4$, $LiNH_2$, and $LiBH_4$ have a low density compared to the conventional shielding material, and have excellent neutron shielding ability, and the gamma ray shielding ability is also good. Mg_2FeH_6 showed 176% shielding ability against gamma rays, and $LiBH_4$ showed 422% neutron shielding ability compared to concrete.

Table 1. Evaluation of shielding ability for lightweight materials using MCNP6 code

No	Material	Density (g/cc)	Gamma flux	Neutron flux
1	Concrete	2.4	1.11E-03	7.95E-04

2	Lead	11.3	4.61E-05	1.30E-03
3	$LiBH_4$	0.666	8.67E-04	6.79E-04
4	Mg_2FeH_6	2.74	1.08E-03	7.44E-04
5	MgH_2	1.45	1.07E-03	8.68E-04
6	B_4C	2.52	1.07E-03	8.26E-04
7	TiH_2	3.76	1.02E-03	6.77E-04
8	LiH	0.78	9.76E-04	8.36E-04
9	$NaBH_4$	1.074	9.69E-04	7.06E-04
10	$LiAlH_4$	0.917	9.64E-04	7.94E-04
11	$LiNH_2$	1.178	9.47E-04	6.94E-04
12	CaH_2	1.7	1.17E-03	7.67E-04
13	BeH_2	0.65	8.63E-04	1.06E-03
14	Iron	7.9	4.52E-04	9.41E-04
15	Tungsten	19.2	3.62E-06	1.54E-03

Based on the high-performance shielding materials such as B, Ta, W, Gd, and others, computer simulation of the composition of hydrogen compounds that do not exist at present is performed as shown in Table 2. The results show that the hydrides such as WBH_4, $LiWH_4$, and $WFeH_6$ have a similar density to the conventional shielding materials and have excellent gamma ray and neutron shielding ability.

Table 2. Evaluation of shielding ability against new non-existent composition using MCNP6 code (density estimation)

No	Material	Density (g/cc)	Gamma flux	Neutron flux
1	$PbBH_4$	9.2	4.67E-04	4.79E-04
2	$CeBH_4$	5.8	4.60E-04	5.83E-04
3	$NdBH_4$	5.9	4.28E-04	5.85E-04
4	$GdBH_4$	6.6	3.36E-04	5.55E-04
5	$TaBH_4$	11.8	5.28E-05	2.54E-04
6	WBH_4	13.0	3.45E-05	2,16E-04
7	$LiWH_4$	14.7	1.60E-04	1.89E-04
8	$WFeH_6$	15.1	2.01E-05	5.06E-05
9	PbB_4C	6.53	8.29E-04	1.01E-03

4. Conclusion

To overcome the disadvantages of conventional radiation shielding materials, new light metal hydride materials were searched through Monte Carlo simulation. As a result, metal hydride materials such as $LiAlH_4$, $LiNH_2$, and $LiBH_4$ exhibited excellent neutron shielding ability while maintaining low density characteristics compared to the conventional shielding materials. Also, simulations were carried out on the composition of metal hydrides that do not exist at present. The results show that hydrides such as WBH_4, $LiWH_4$, and $WFeH_6$ have a similar density to the existing shielding materials, but have excellent neutron and gamma ray shielding ability.

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