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Evaluation of Neutron shielding efficiency of Metal hydrides

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1. Introduction

Neutron shielding is achieved of interaction with material by moderation and absorption. Material that contains large amounts hydrogen atoms which are almost same neutron atomic weight is suited for fast neutron shielding material. Therefore, polymers containing high density hydrogen atom are being used for fast neutron shielding. On the other hand, composite materials containing high thermal neutron absorption cross section atom (Li, B, etc) are being used for thermal neutron shielding. However, these materials have low fast neutron absorption cross section. Therefore, these materials are not suited for fast neutron shielding.

Hydrogen which has outstanding neutron energy reduction ability has very low thermal neutron absorption cross section, almost cannot be used for thermal neutron shielding. In this case, a large atomic number material (Pb, U, etc.) has been used.

Thus, metal hydrides are considered as complement to concrete shielding material. Because metal hydrides contain high hydrogen density and elements with high atomic number.

In this research neutron shielding performance and characteristic of nuclear about metal hydrides ((TiH_2, ZrH_2, HfH_2) is evaluated by experiment and MCNPX using ^{252}Cf neutron source as purpose development shielding material to developed shielding material

2. Code Simulation

Monte Carlo transport code MCNPX (Version 2.5.0) was used for neutron shielding performance of metal hydrides.

Simulation was used for ^{252}Cf neutron source. Neutron spectrum data of ^{252}Cf in MCNPX was used in this source simulation. Strength of source model is 10 mCi

Increasing the thickness of shielding material up to 8 cm, interval 1 cm, By calculating the intensity of neutrons were compared with experimental data about three of metal hydrides (TiH_2, ZrH_2, HfH_2)

Shielding materials were simulated diameter 4 cm length 30 cm and located 100 cm from ^{252}Cf for evaluate shielding characteristic of each of metal hydrides.

Material properties of three of metal hydrides (TiH_2, ZrH_2, HfH_2) are given in the Table Ⅰ.

Table Ⅰ. Material Properties

Materials	*σ (g/cm3)*	*Weight (g/mole)*	*H Concent.*	*H density*	*Neutron absorption Cross-section*
ZrH_2	*5.6*	*93.24*	*2*	*7.23123 E+23*	*0.194*
TiH_2	3.75	49.883	2	9.05118 E+23	6.092
HfH_2	11.4	180.506	2	7.60396 E+23	105

3. Experiment

Neutron source was determined ^{252}Cf and Shielding materials were determined TiH_2 (99%, T-1101, Cerac, Inc.), ZrH_2 (99.7%, Z-1094, Cerac, Inc.), HfH_2 (99.8%, H-1008, Cerac, Inc.) like simulation. Shielding experiment was performed at neutron shielding experiment facility in KAERI (The Korea Atomic Energy Research Institute).

Geometry used to experiment is given in the Fig. 1. ^{252}Cf neutron source was located under the shielding experiment equipment, shielding material container was located between neutron detector and neutron source. And then, shielding materials were installed in container. Neutron shielding performance was measured by kind of material and thickness condition after penetrate shielding material.

Powder type specimen was used to easily measure neutron intensity over increase the thickness of shielding materials. These powder particle size is 10 ㎛.

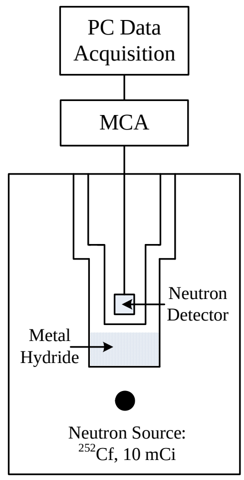

Fig 1. Schematic diagram of neutron shielding capability assessment apparatus

Shielding material container was made of aluminum and cylindrical shape (Diameter 37 mm, High 173 mm). Specimen was put into a container between 0 - 5 cm and covered a cap to adjust the height.

There is channel (Diameter 8 mm) in a cap for neutron detector sensor contact to cap.

Shielding performance was evaluated by neutron from ^{252}Cf irradiating to of metal hydrides powder for 300 sec.

4. Results and Discussion

Simulation results tend to match experiment data in all of metal hydrides. However, as shielding material get thicker, shielding performance of experimental results is lower than simulation results. These results are the cumulative effect of porosity. Because pore was produced in increasing the thickness of shielding.

When calculated only neutron shielding rate, HfH_2 is best shielding material and ZrH_2 is worst shielding material in Fig. 2. In ZrH_2 case, neutron intensity increased up to thickness 3 cm and then decreased. Because fast neutron backscattering up to thickness 3 cm and irradiated neutron from source were measured by cumulative. This phenomenon is clearly shown in ZrH_2 which has the lowest fast neutron absorption cross section.

Simulation results of TiH_2, Zrh_2, HfH_2 in Fig 2. In the fig 2, Results is shown difference neutron intensity at same simulation. Because quantity of backscattered neutron is different by difference of absorption cross section of shielding material.

Neutron absorption cross section of ZrH_2 is 0.194 barn in Table 1. Therefore, high neutron intensity is shown by backscattered neutron. However, in contrast, reduction rate is very high. Therefore purpose for reduction energy is considered effective.

In contrast, Neutron absorption cross section of HfH_2 is 106 barn in Table 1. HfH_2 doesn't produced backscattered neutron and show remarkable energy reduction. However, Hf is not widely used in industry and it has been identified as strategic material as strategic material. Therefore, development of shielding using Hf is remaining problem.

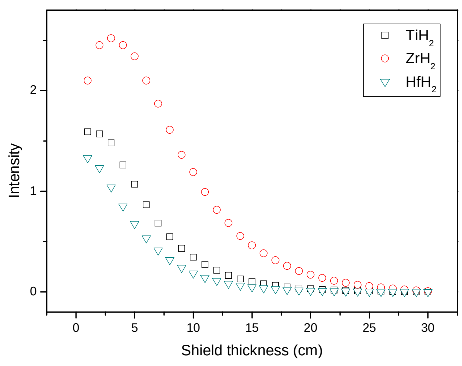

Fig 2. Neutron shielding performance by MCNPX

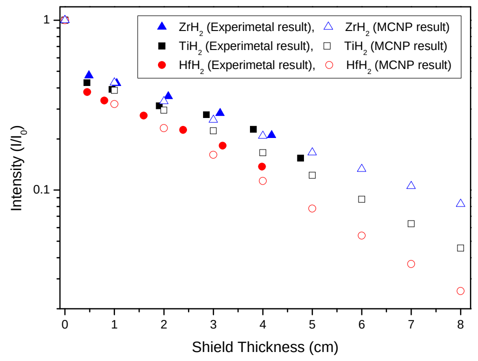

Fig 3. Neutron shielding performance of metal hydrides (Experimental results vs MCNP results)

5. Conclusions

In domestic, neutron accelerator is determined adopt, neutron shielding problems are more interested in gathering. Therefore, research and development of shielding material to complement concrete is needed.

In research, TiH_2, ZrH_2, HfH_2 is evaluated by MCNPX about neutron shielding performance from ^{252}Cf.

Neutron shielding performance of HfH_2 is proved remarkable shielding material to neutron by results of experiment and simulation.

Strength of neutron source from ^{252}Cf is reduced to 10% by 4.3 shield thickness of HfH_2. 5.5 cm of shield thickness of TiH_2 and 7.4 cm of shield thickness of ZrH_2 is needed to get same results

If composites containing of metal hydrides are constructed based on this research, shielding material is able to developed more effective than concrete. And if absorption layer and reduction layer were consisted mixed layer for neutron shielding, more efficient shielding material is expected to be found.

REFERENCES

[1] Faiz M. Khan: The Physics of Radiation Therapy, 3rd ed., Lippincott Williams & Wilkins, Baltimore, 2003

[2].Paul J. Early, D Bruce Sodee: Principles and Practice of Nuclear Medicine, 2nd ed., Mosby Year Book, Inc., St. Louis, Missouri, 1995

[3] A. Facure, R.C. Falcão, A.X. Silva, V.R. Crispim, J.C. Vitorelli: A study of Neutron Spectra from Medical Linear Accelerators, Applied Radiation and Isotopes, 62, 69-72, 2005

[4] Y. C. Lo, G. Yasuda, T.J. Fitzgerald, M. M. Urie: Intensity Modulation for Breast Treatment Using Static Multi-leaf Collimators, International Journal of Radiation Oncology. Biology. Physics, 46(1), 187-194, 2000