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Study of the Shielding Performance of W and Pb under the Neutron Irradiation based on MCNP

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Abstract

Based on MCNP, the shielding properties of lead-tungsten core materials for neutrons are studied in this paper, there are six shielding materials, such as Pb, W, Cu, Fe, graphite-C and Krafton-HB, were selected to test the neutron shielding ability of single material and composite material. The thickness of shielding material and the energy of neutron source are used as variables to measure the change of shielding performance of neutron with two variables. In neutron shielding, we usually choose lightweight materials with smaller atomic number, but this material has poor shielding ability for neutrons with higher energy. So we selected that W material with better slowing energy and boride resin material with better absorption ability can be used as composite core material to compare with single material. Based on MCNP, this paper carries out physical and geometric modeling of the experimental object, chooses a neutron source of certain energy to be placed in a fixed position, fixes the shielding material in a fixed position, and tests its shielding ability by detecting the neutron flux passing through the surface of the shielding material. The final experimental results show that: W is the best material to slow down high-energy neutrons, followed by Fe, Pb, graphite-C and Cu, and Krafton-HB is the worst material to slow down high-energy neutrons.

Keywords

MCNP; Neutron shielding; Tungsten; Krafton-HB; Composite Core Board Material.

1. Introduction

In this article, six shielding materials are selected for comparison, and a model is established in MCNP. By comparing the slowing down shielding ability of each material to 14MeV neutrons and the shielding ability of different energy neutrons under the same thickness. This measurement selects six materials for measurement calculation, including four metal materials, in order: Pb, W, Fe and Cu, and two kinds of neutron absorption are better The lightweight materials are graphite C and Ktafton-HB.

2. Experimental Steps

1. The thickness-dependent slowing capacity of neutrons at 14 MeV is measured for different types of shielding materials and compared with each other. The neutron source intensity is 14 MeV, the shielding material is a single material, the distance from the source is 10 cm, and the thickness is 2 cm, 4 cm, 6 cm, 8 cm, 10 cm. The detection card calls the threshold function to detect the neutron injection of 14 MeV through the shielding material.

2. Measure the thickness-dependent variation of the shielding capacity of different types of shielding materials for neutrons of 14 MeV. The neutron source intensity is 14 MeV, the shielding material is a single material, the distance from the source is 10 cm, and the thickness is 2 cm, 4 cm, 6 cm, 8 cm, 10 cm, the detection card calls the F1 card, detects the number of neutrons passing through the shielding material, and uses this index to express the shielding performance of each material.

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3. Modeling

In order to be able to carry out idealization experiments without the influence of the external environment, we delineate a spherical space with a radius of 80 cm, fill the spherical space with air, stipulate that the external region of the sphere is a vacuum state, place a one-way neutron source of the specified energy at the position of the center of the sphere, and then place a shielding material body with a length of 30 cm, a width of 30 cm, and a certain thickness 10 cm away from the source. The shielding performance of the material is illustrated by measuring the amount of neutron injection through the shield material as an index. The basic geometrical model is shown in Figure 1.

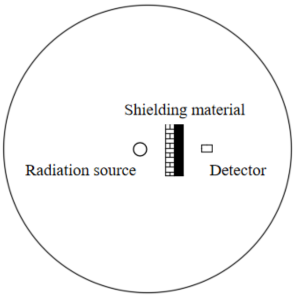

Figure 1. Geometric Model

4. Data Processing

By reading the output file, we can see that the slowing capacity of different materials for 14 MeV neutrons varies with the thickness of the shielding material, and by shielding the same material we can see that the neutron injection decreases exponentially with increasing thickness. For the same thickness, the material with the best moderating ability is tungsten, with a 20 cm tungsten moderating ability of about 99%, and the material with the worst moderating ability is resin, with a 20 cm resin moderating ability of about 88%, as shown in Table 1.

Table 1. Slowing capacity of different materials with different thicknesses for 14 MeV neutrons.

	2.5cm	5.0cm	7.5cm	10.0cm	12.5cm	15.0cm	17.5cm	20.0cm
W	0.7219	0.1783	0.0756	0.0316	0.0133	0.0057	0.0024	0.0010
Cu	0.7016	0.4938	0.3469	0.2440	0.1716	0.1208	0.0851	0.0595
Fe	0.5761	0.3317	0.1917	0.1109	0.0638	0.0366	0.0209	0.0122
Pb	0.6363	0.4054	0.2579	0.1646	0.1052	0.0668	0.4231	0.0268
graphite C	0.6899	0.4758	0.3300	0.2286	0.1576	0.1090	0.0756	0.0514
Krafton-HB	0.7597	0.5775	0.4391	0.3336	0.2538	0.1931	0.1468	0.1212

After comparing the slowing ability of each material, and then the shielding performance of each material, we can know from reading the output file that the material with the best neutron shielding ability to 14 MeV is tungsten, 40cm tungsten can shield 98% of the neutrons, followed by copper and iron, the worst effect is lead, 40cm lead's shielding ability is only about 85%. The specific data are shown in Table 2.

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Table 2. Shielding capacity of 14 MeV neutrons for different materials and thicknesses.

	5.0cm	10.0cm	15.0cm	20.0cm	25.0cm	30.0cm	35.0cm	40cm
W	0.9204	0.7453	0.5236	0.3251	0.1824	0.0987	0.0494	0.0237
Cu	0.8013	0.6299	0.4706	0.3315	0.2224	0.1438	0.0906	0.0555
Fe	0.7892	0.6131	0.4590	0.3320	0.2324	0.1624	0.1212	0.0763
Pb	0.9571	0.8647	0.7296	0.5793	0.4368	0.3172	0.2222	0.1540
graphite C	0.8050	0.6398	0.4970	0.3743	0.2736	0.1927	0.1329	0.0894
Krafton-HB	0.8712	0.7004	0.5326	0.3884	0.2756	0.1905	0.1292	0.0853

As can be seen from Figure 2, the slowing performance of several materials on neutrons shows an exponential downward trend with increasing thickness, in several materials, according to the shielding performance from good to bad for tungsten, iron, lead, graphite, copper and borinated resin. Among them, the best shielding performance of tungsten, the shielding effect reached 60% when the thickness of 2cm, while the borinated resin at 4cm shielding effect only close to 60%; six shielding materials except for borinated resin, the other five materials in 10cm slowing effect is higher than 90%, of which the best slowing effect of tungsten even reached 99.9%.

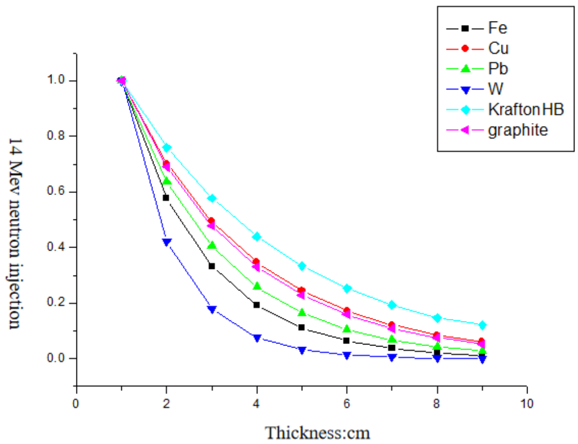

Figure 2. Variation of neutron slowing properties of different materials on 14 MeV neutrons with thickness

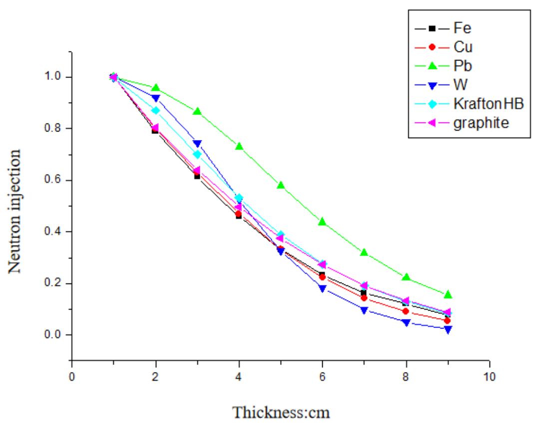

Figure 3. Thickness-dependent variation of neutron shielding properties of different materials for 14 MeV

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As can be seen from Figure 3, different thicknesses of different kinds of shielding materials on the neutron shielding ability of the ranking is different, of which the most obvious is the tungsten shielding material, at a thickness of 5cm, tungsten shielding ability is only slightly better than lead and inferior to other shielding materials, while at 15cm, tungsten shielding performance and other four kinds of shielding material shielding ability is similar, can reach about 55%! At 40 cm, tungsten is again the material with the best shielding effect. In addition to tungsten and copper, the shielding effectiveness of the four materials was similar, with lead having the worst shielding effect.

5. Conclusion

According to the above experimental data and data processing images, for the image of Figure 2 we can see that the metal has a certain slowing ability for high-energy neutrons. The most effective of these is the tungsten shielding material. Lead is the third slowing ability, but the shielding effect for high-energy neutrons is too poor, so lead is not used to shield the neutrons. The more obvious point in Figure 3 is that the boriding resin has very good shielding ability for low-energy neutrons, so we thought of using tungsten with good slowing ability to slow high-energy neutrons into low-energy neutrons, and then use the boriding resin to absorb low-energy neutrons, taking the advantages of both to combine to form a composite core plate material, which is also one of the advantages of the core plate material, compared to a single material is more flexible.

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