STUDY OF CERAMIC MIXED BORON ELEMENT AS A NEUTRON SHIELDING

Ismail Mustapha, Mohd Reusmaazran Yusof, Md Fakarudin Ab Rahman, Nor Pa'iza Mohamad Hasan, Samihah Mustaffha, Yusof Abdullah, Mohamad Rabaie Shari, Airwan Affandi Mahmood, Nurliyana Abdullah, Hearie Hassan

Plant Assessment Technology
Industrial Technology Division, Malaysian Nuclear Agency
Bangi, 43000 KAJANG, MALAYSIA

Email : ismail@nuclearmalaysia.gov.my

ABSTRACT

Shielding upon radiation should not be underestimated as it can causes hazard to health. Precautions on the released of radioactive materials should be well concerned and considered. Therefore, the combination of ceramic and boron make them very useful for shielding purpose in areas of low and intermediate neutron. A six grades of ceramic tile have been produced namely IMN05 - 5% boron, IMN06 - 6% boron, IMN07 - 7% boron, IMN08 - 8 % boron, IMN09 - 9% boron, IMN10 - 10% boron from mixing, press and sintered process. Boron is a material that capable of absorbing and capturing neutron, so that neutron and gamma test were conducted to analyze the effectiveness of boron material in combination with ceramic as shielding. From the finding, percent reduction number of count per minute shows the ceramic tiles are capable to capture neutron. Apart from all the percentage of boron used, 10% is the most effective shields since the percent reduction indicating greater neutron captured increased.

ABSTRAK

Pemerisaian radiasi tidak boleh dipandang ringan kerana ia boleh memudaratkan kesihatan. Langkah berjaga-jaga terhadap bahan-bahan radioaktif yang dikeluarkan hendaklah dititikberat dan dipertimbangkan dengan baik. Oleh itu, gabungan seramik dan boron menjadikannya sesuatu yang sangat berguna sebagai perisai di kawasan neutron yang yang bertenaga rendah dan pertengahan. Sebanyak enam gred jubin seramik telah dihasilkan iaitu IMN05 - boron 5%,

IMN06 - boron 6%, IMN07 - boron 7%, IMN08 - boron 8%, IMN09 - boron 9%, IMN10 - boron 10% daripada pencampuran, pemampatan dan proses tersinter. Boron adalah bahan yang mampu menyerap dan menangkap neutron, oleh itu ujian neutron dan gamma telah dijalankan untuk menganalisa keberkesanan bahan boron dengan kombinasi seramik sebagai perlindungan. Daripada dapatan, peratusan pengurangan bilangan per minit menunjukkan jubin seramik mampu untuk menangkap neutron. Berbading dengan semua peratusan boron yang digunakan, 10% adalah perisai yang paling berkesan di mana peratus pengurangan bilangan menunjukkan neutron yang ditangkap lebih meningkat.

Keywords: Neutron shielding; Boron; Ceramics;

INTRODUCTION

There are needs to provide and ensuring a safe condition at a workplace to which it applies to a place of mostly involves hazardous material such as radioactive source. Radiation of radioactive materials is very harmful and therefore, precaution on this matter should be well concerned. In this case, the needs are diversifying to build the efficient material for neutron shielding in laboratory. Currently, combination of ceramic and boron makes them very useful for material shielding in areas of low and intermediate neutron flux. Neutron flux is referring to the number of neutrons passing through an area over a span of time. Significantly, the boron content is able to attenuate thermal neutrons and captured the neutron due to its excellent nuclear and physical characteristics.

Ceramics is the art and technology of forming, firing and glazing natural clays in order to get a range of product for example ceramic tiles. It is usually made from a mixture of clay, water, feldspar, talc, flint and other naturally occurring minerals. The mixture is then pressed into shape and finished using either a single-fired or double-fired process. Most ceramics are hard, good corrosion resistance and poor conductors of heat and electricity. Ceramic product can be use includes in structure, refractoriness and white ware sectors (Hill, 2002).

The source of neutrons is primarily nuclear reactions, such as fission, but they may also be produced from the decay of radioactive nuclides. Californium-252 is the example for spontaneous fission source of neutron (Hamilton, 2006). Neutron radiation is a form of ionizing

radiation most often found in nuclear reactors and nuclear bombs. Neutron radiation is a health risk; therefore a good neutron shielding material was desired in order to reduce the worker exposure to the radiation. Hydrogen in water is an example of a good neutron shield and this low number mass of material are best in slowing down neutron. Other materials are sometimes used that have much greater affinities for capturing the slow neutrons than hydrogen does is boron.

Boron is metalloid element that is important material use for nuclear applications. It is because due to its high neutron absorption cross section and its ability to capture neutrons makes it effective for radiation shielding. This boron isotope is excellent at capturing thermal neutrons when combined as a carbide or oxide.

The boron fiber neutron shielding properties have been studied by Joseph et al. (2010). Boron fiber, boron nano powder, and enriched 10boron carbide (10B4C) in various combinations, configurations and thicknesses, dispersed or embedded into a high temperature thermoset epoxy resin were compared for their shielding effectiveness.

A proper radiation protection is needed in order to protect body against harm. This protection is depends on the basic radiation protection which is time, distance and shielding. For this paper, the focus is based on the shielding protection. The objective of this paper is to show the analyses and testing result of boron material in combination with ceramic as neutron shielding.

METHODOLOGY

This paper is about analyses and testing the effectiveness of boron material in combination with ceramic for neutron shielding. Basically, this study comprises five major steps in order to obtain the final results for each analysis that is meant to be done. This research can be divided into two parts. The first part is involving the processing of ceramics sample. It begins with the preparation of raw materials. Then, it proceeds with shaping process. Later, drying process will take place and then final stage will be firing or sintering. The second part is focusing more onto the two tests that will be performed to analyze the ceramics sample. The two tests are known as mechanical test and radiation test. For this paper, only radiation test will be discussed.

Neutron Source

Neutron test was using Californium-252 (Cf-252) with activity of 1.6 μCi and 0.49μCi. Californium-252 is a very strong neutron emitter, with one microgram emitting 170 million neutrons per minute. Thin foils containing californium-252 can be used as a source of fission fragments for research purposes. Californium-252 can also be used as a portable neutron source to identify gold or silver ores through neutron activation analysis, and it can be used in moisture gauges to locate water and oil-bearing layers in oil wells. That is why ^{252}Cf is used in conducting neutron test for ceramic samples.

Radiation Test

This test is basically involves the use of radioactive sources to check the shielding responds of ceramic samples added with boron. There were all together three tests were running at different time and day. Three series of test were conducted with three different distances to obtain the most accurate and best results and analysis on the ceramic samples. Before hand, background counting (test) was taken for stabilizing the counter and detector. Then, only source was placed to perform air count test. Later, counting in count per minute (CPM) was taken by placing the ceramic sample based on the percentage, temperature and distance accordingly. The ceramic sample was ranging from 5% boron to 10% boron. Counting was done three times and the average values will be calculated to obtain one finite value.

DISCUSSION

Thermal neutron refers to the slow neutrons that wanted to be analyzed whether the boron content has the ability to capture them or not. In this experiment, the test conducted with angle of 90° of the detector placement from the source. 90° angle was chosen to allow for higher scattering effects when source was radiated towards the ceramic sample. The schematic diagram in Fig. 1 shows how the scattering effect looks like.

From the data recorded, it can be seen that the count value from all of the experiment was reduce when compared to the controlled sample count reading. The thermal neutron which was emitted is then hit the ceramic sample. The ceramic sample is contains the various percent of boron act as neutron shielding by absorbed or capture neutron. Since there is boron in the

ceramic sample, so the emitted neutron was captured by boron and give lower count reading compared to the sample that do not contain boron.

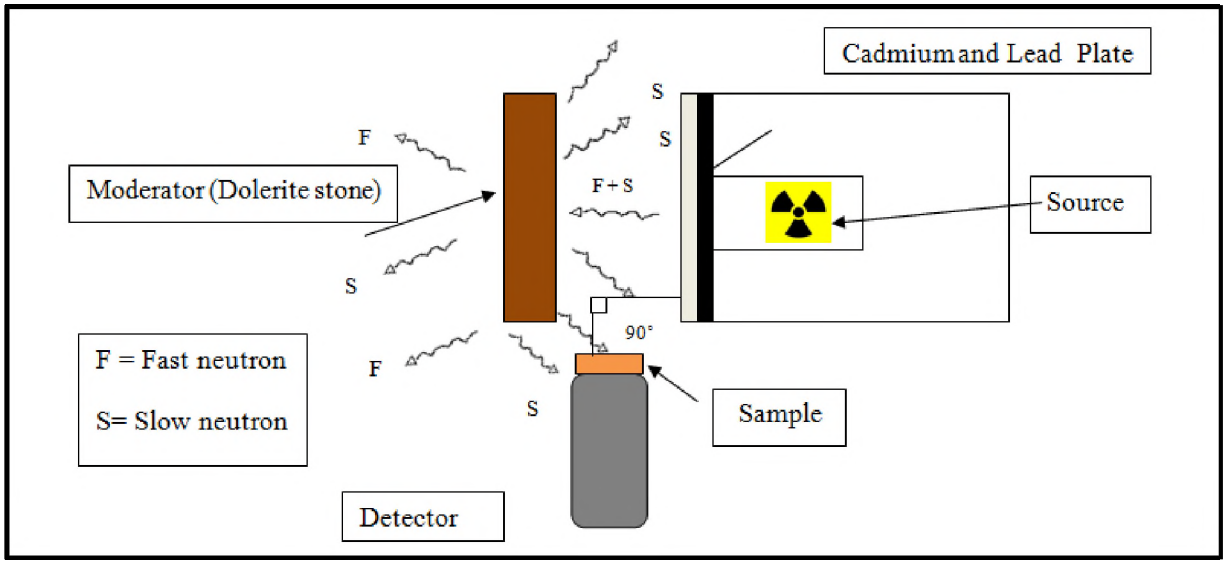
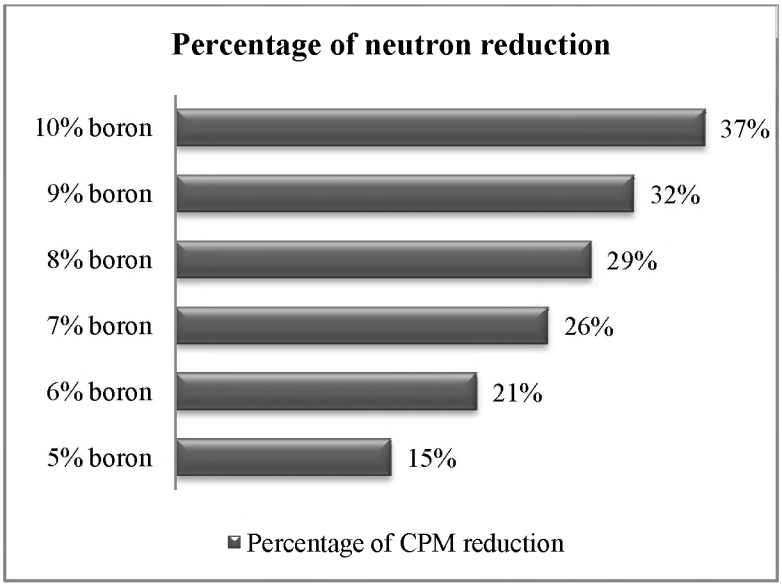


Figure 1: Thermal neutron test schematic diagram

Hypothetically, increasing percent boron in ceramic sample will increase the percent reduction. From the plotted graph, data from the experiment shows the highest percentage of reduction is at 10% boron. This shows the most effective sample that used to capture neutron was sample with 10% boron.



Graph 1: Percentage of CPM reduction with every type of ceramic

CONCLUSION

A ceramic tile has dominated most application of building and construction industry and safety is indeed important especially at workplace when mostly involve hazardous material such as radioactive material. In a view of that fact lead the study about ceramic tiles as neutron shielding for nuclear laboratory application had been conducted. After various tests being carried, we find that various grades of ceramic tile that made of additional 5% boron to 10% boron successfully obtained and can be use in the laboratory as a neutron shielding. Boron content in ceramic tiles is capable to capture both fast and slow neutron and it is proven by reduction percent of count per minute. The highest percent of boron content in ceramic which is 10% is the most effective medium to shield neutron.

REFERENCES

1) Hamilton, D. (2006). Neutron Interactions with Matter. *Radioactivity - Radionuclides - Radiation* , 1-14

2) Joseph W. Hanafin, William Grant, Specialty Materials, Inc. Lowell,Leo Bobek, Thomas Regan, UMass Lowell, Radiation Laboratory, Lowell. (2010). *Boron Fiber Neutron Shielding Properties*.