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Research Article

Fast Neutrons Shielding Properties for Fe_2O_3 added Composite

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Abstract:

Neutron has been one of the most interesting particle since its discovery. Being an uncharged particle it is more difficult to shield in comparison with the other radiation types. This may be due to the differences of its interaction with matter. The main interaction processes of neutron with a matter may be via (n,p) reaction and thus hydrogenous materials are generally preferred to shield neutron. In this study neutron shielding properties for HAP composites have been investigated. This is done using Phy-X/PSD software.

1. Introduction

All alive are exposed to many types of radiation sourced due to natural or man-made. Especially in the 20th century when neutron is discovered and radiation started to be used in a variety of different fields, the radiation protection science developed. This was required due to the radiation hazardous effect to human cell. In order to be protected from radiation of X-rays, gamma rays and neutrons, there are three basic methods of time, distance and shielding. Beside first two methods the shielding is most important. Although lead and lead based materials are conventional materials for radiation shielding different types of materials have been studied as alternative [1-21].

As the neutron shielding is more difficult than others it is important to know neutron interaction with the matter. Being electrically neutral particle, neutron interacts only weakly with matter into which it can penetrate deeply. On the other hand gamma-rays interact dominantly with the electron shell of the atom, the neutron does on the level of the nucleus. This makes neutron quite sensitive to light atoms such as hydrogen, oxygen, etc. Those atoms have much higher interaction probability with neutrons than with gamma-rays. For neutron shielding the universal law of attenuation of radiation passing through matter (Beer-Lambert law) is valid. The neutron interaction mechanisms with a material may vary with the energy of incoming neutron and also the physical properties of the target nuclei. The total microscopic cross section (σ_t) of neutrons of any energy expresses the probability of the interaction with the medium and it is given as in equation 1.

$$\sigma_t = \sigma_s + \sigma_a \qquad (1)$$

where σ_s is the both inelastic and elastic scattering while σ_a includes nuclear fusion, nuclear spallation and capture of neutrons.

The fast (or fission energy) neutron attenuation is called the fast neutron effective removal cross section (FNRCS) plays an important role to express for neutron shielding properties. As it serves well for situations when there is not sufficient hydrogen in the material, it is worth calculating the removal cross sections of different materials. The removal cross section is defined as the probability of a first collision which removes that neutron from its uncollided fast group [22] and it is obtained using equation 2.

$$\Sigma_R = \Sigma_i \rho_i \left(\frac{\Sigma_R}{\rho}\right)_i \qquad (2)$$

where $\rho_i = \rho w_i$ is the partial density, (w_i is the weight fraction of element i) and ρ is the total density of the material. Weight fraction is the ratio of the molar weight of related element to the molar weight of the material [23-27].

In this study, the fast neutron removal cross section (FNRCS) and attenuation length (mfp) of four different type HAP composite have been calculated and the effect of Fe_2O_3 rate on this parameter were also investigated.

2. Materials and Methods

The fast neutron removal cross section (FNRCS) and attenuation length (mfp) properties of four different composite materials have been investigated. As a material Hydroxyapatite (HAP) composite is used and Fe_2O_3 is doped in different rate. The chemical formulation of composite is expressed as (*100*-*x*)HAP+*x*Fe_2O_3 where x= 0, 2.5, 5, and 7.5 (wt%), using Phy-X/PSD code. The Phy-X/PSD is a free online platform where radiation shielding parameters of any materials can be obtained [28].

3. Results and Discussions

The neutron attenuation properties of four different types of composites have been obtained in term of fast neutron removal cross section (FNRCS) and attenuation length (mfp). The obtained results are shown as a function of density of composite Fig. 1. It is seen from this figure that the FNRCS increased with the increasing density of composite. This could be the results of increasing Fe_2O_3 rate in the composite. This is shown in Fig. 2 where it can be clearly seen that Fe_2O_3 rate is important for neutron shielding capability of this composite. This can also be seen in Fig. 3 where attenuation length is displayed as a function of density. It is clearly seen from this figure that the mfp decreased linearly with the increasing density which means that the high density composite may stop neutron in short distance.

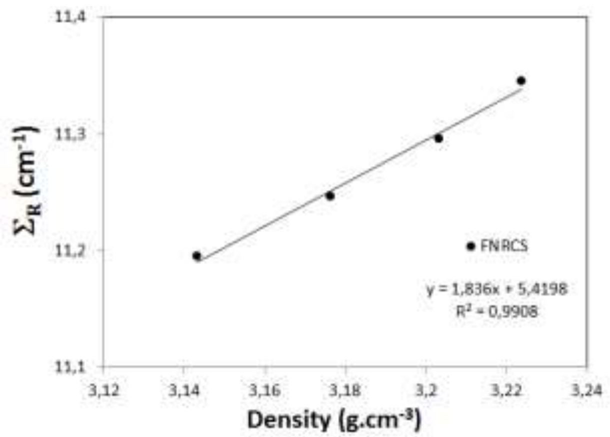

Figure 1. *Neutron removal cross section as a function of composite density*

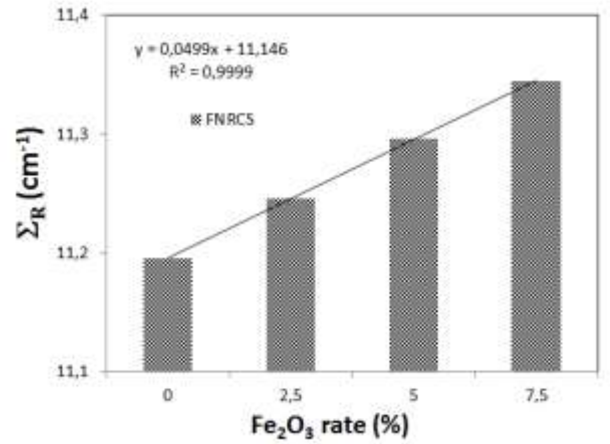

Figure 2. *Neutron removal cross section as a function of Fe_2O_3 rate in composite*

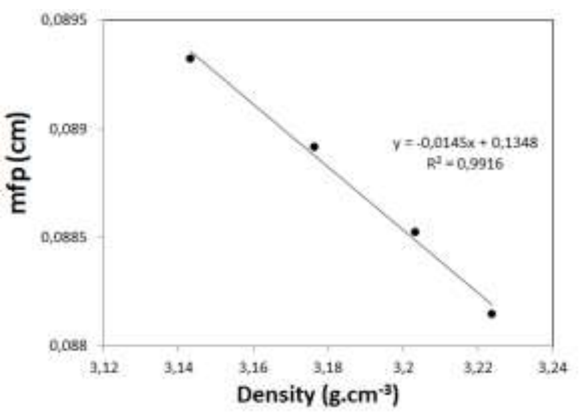

Figure 3. *Attenuation length as a function of composite density*

Author Statements:

- The authors declare that they have equal right on this paper.
- The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- The authors declare that they have nobody or no-company to acknowledge.

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