Advanced Physical Research
Vol.1, No.1, 2019, pp.32-36

DETERMINATION OF GAMMA RAY ATTENUATION OF WC-6 wt %Co MATERIALS AGAINST Co-60 GAMMA RADIOISOTOPE SOURCE

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Abstract. In this paper, the cobalt cemented tungsten carbide samples (WC-6wt%Co) were investigated in order to obtain linear attenuation coefficients (μ), mass attenuation coefficients (μ/ρ) and half value thickness (HVL) by gamma transmission technique using ^{60}Co gamma source at 1.25 MeV gamma ray energy. NaI(Tl) scintillation detector was used for detection of gamma rays in the experiments. The experimental results of the WC-6wt%Co composites were compared with the theoretical values which were obtained XCOM computer code. The evaluated results showed that the difference between the experimental and theoretical values was under 5%. In addition, WC-6wt%Co samples were compared the other shielding materials such as pure tungsten, lead and WC-Co samples which include different ratio cobalt by weight. The gamma linear attenuation value of the WC-6wt%Co samples was appropriate for shielding. Therefore, it could be said that WC-6wt%Co samples can be considered as an alternative material instead of lead (Pb) for gamma shielding process.

Keywords: *Co-60,tungsten carbide, XCOM, composite material, gamma transmission.*

PACS*– 25.20.Dc, 81.05.Mh, 28.52.Fa*

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Manuscript received: *17 May 2019.*

1. Introduction

Tungsten or owing to other name Wolfram is an element has incredibly dense and hard and having a high melting point (Rumble, 2018). Tungsten used as alloy or composite forms due to having appropriate manufacturing properties. Therefore, tungsten-based materials are preferred as high-tech materials like nuclear applications, shielding materials and for new generation reactors (Leonard, 2012; Chen *et al*., 2015; Buyuk & Togrul, 2014; Demir *et al*., 2017). In the meantime, tungsten composites are suggested for fusion reactor systems especially.

Gamma-ray attenuation is dependent upon the density of the shielding material. It can be said that a dense shield material with a higher the atomic number is a better shielding materials for gamma-rays. Lead is an element heavier than about 80% of the elements in the periodic table. Less dense shielding materials need a greater thickness than a heavier material for providing the same gamma shielding properties. If we evaluate the economic suitability of the material to be used as armour, lead will be much more cost-effective than tungsten. On the other hand, lead is a hazardous material for environment. In addition, lead is not effective against all types of radiation. High energy electrons (including beta radiation) incident on lead may create bremsstrahlung radiation, which is potentially more dangerous to tissue than the original radiation. Moreover, lead is not a particularly effective absorber of neutron radiation.

WC based materials widely used as hard materials, in the various field with having high hardness and good wear resistance (Demir *et al*., 2017; Highton, 1983). Cobalt is used for a binder phase element for owing to the wet ability to WC (Liua *et al*, 2017; Fan *et al*., 2013). After accepting of the European Union (EU) directive about the restriction of using lead, many materials have investigated instead of lead usage especially for shielding materials (Al-Sarray *et al*., 2017; Davraz *et al*., 2017; Buyuk *et al*., 2015; Gurler & Tarim, 2016). One of the suggested material is WC-Co composite materials as shielding. In this study, it is aimed to determine the shielding properties of cemented tungsten carbide against the gamma ray above 1 MeV.

2. Experimental procedures

Tungsten carbide samples 6 wt. %Co (WC-6wt%Co) had been produced by mechanical alloying (MA) method as a trade material. Cobalt-60 radioisotope preferred as a gamma source due to high energy emitting with 1,17 MeV and 1.33 MeV energy peaks. Therefore, shielding capability examined by using over 1 MeV energy level.

Experimental set up arranged according to principle of transmission technique (Demir *et al*., 2017; Tugrul *et al*., 2016). NaI(Tl) scintillation detector (Canberra Model (802-2X2)) that has 5.5 cm diameter and 14-pin tube was used for radiation measurement. A collimator placed in front of the detector with 5 mm diameter and supplied the good geometry condition. DigiBASE model PMT base compact with preamplifier, bias supply, and multichannel analyser (MAESTRO-32 MCA Emulation software) were connected with the experimental set up and counted the gamma rays. Experimental parameters can be seen in Table 1

Table 1. Experimental parameters

Parameters	**Explanation**			
Gamma Source	Co-60 Radioisotope	Energy 1.17 MeV & 1.33 MeV	Av. Energy 1.25 MeV	Half-Life 5.3 y
Experimental Setup	Detector Counting System Collimator	NaI(Tl) Scintillation Detector Multichannel Analyser Mounted type Lead collimator with 5mm hole		

Initially, background radiation measured for the laboratory media. Then net initial gamma intensity (I_o) counted without any material and subtracting the background. After that the net gamma intensities (I) for the each sample determined and relative intensities were found as;

$$I / I_o = e^{-\mu x} \quad (1)$$

where μ represents linear attenuation coefficient and x is thickness. Mass attenuation coefficient (μ_m) calculated as linear attenuation coefficient divided by density (ρ);

$$\mu_m = \mu/\rho \quad (2)$$

3. Results and discussion

Experimental results for WC-6wt%Co samples were collected and drawn a graph that shown in Fig. 1. The results were comparing with another WC-Co composite (15wt%Co) (Buyuk & Tugrul, 2014) that has more than two times Co amount in it according to the studying samples in Fig.2. It can be seen that the for WC-6wt%Co attenuation is nearly close the WC-15wt%Co attenuation but some appropriate in spite of having conventional production process. Furthermore, linear attenuation coefficients of WC-6wt%Co were compared with pure tungsten and lead (Buyuk & Tugrul, 2014) for1.25 MeV energy in Fig 3.

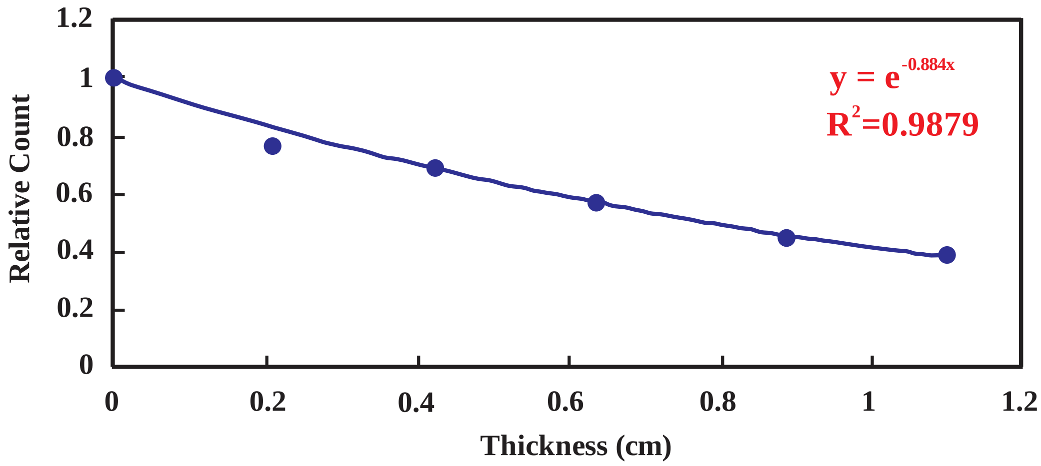

Figure 1. Gamma attenuation curve of WC-6wt%Co

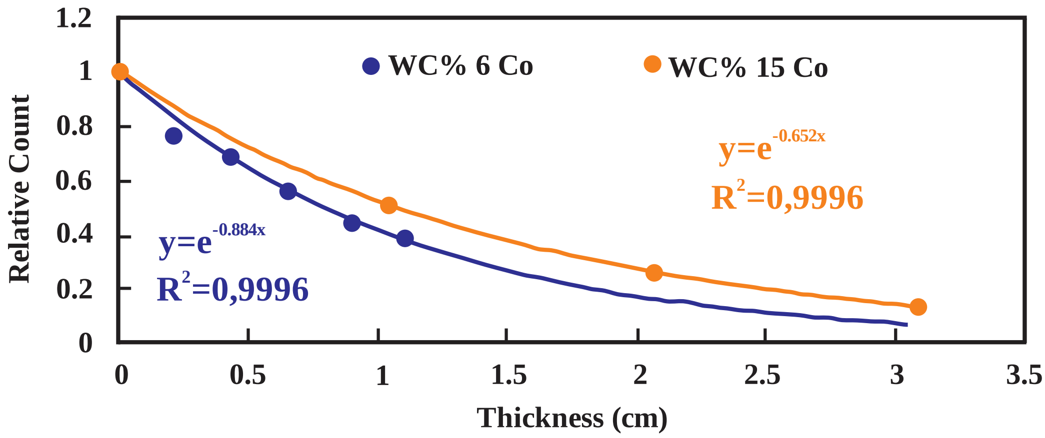

Figure 2. Comparative Gamma attenuation curves for WC-6wt%Co and WC-15wt%Co

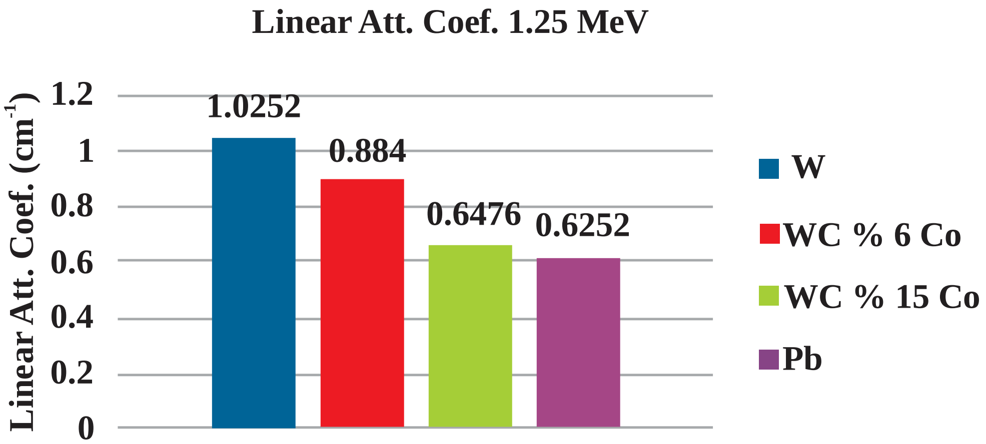

Figure 3. Comparison of linear attenuation coefficients for WC-6wt%Co and WC-15wt%Co, W and Pb

Mass attenuation coefficient was calculated for WC-6wt%Co by using experimental results. Then theoretical mass attenuation coefficient found by using XCOM computer code (Berger *et al.*, 2019). Comparison of the experimental and theoretical mass attenuation coefficients is given in Table 2. Differences between experimental and theoretical values are below 5%. It can be said that reason of the differences related with manufacturing process. However, it considered that it was acceptable.

Table 2. Experimental and Theoretical mass attenuation coefficient of WC-6wt%Co

Mass attenuation coefficient [10^{-2} . cm^2/g]		
Experimental	Theoretical (XCOM)	Difference (%)
5.93	5.64	4.89

Half value layer (HVL) is calculated for WC-6wt%Co as;

$$HVL = 0.693 / \mu \quad (3)$$

and found that is 0.78 cm (with standard deviation of 0.07).

4. Conclusion

With this study, WC-6wt%Co searched the behavior of 1.25 MeV gamma energy and examined whether shielding capability it is appropriate or not. Gamma linear attenuation coefficients were calculated by using experimental data. Mass attenuation coefficient was calculated experimentally or theoretically via XCOM Computer code. The gamma attenuation of the WC-6wt%Co samples was found acceptable for shielding point of view when comparing the lead. With the results of the study, shielding properties of WC-6wt%Co suitable for radiation protection against the gamma ray As known that directive of European Union suggested restriction of using lead, Therefore, it could be said that WC-6wt%Co samples can be considered as an alternative material instead of lead (Pb) for gamma shielding process.

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