INVESTIGATION ON THE EFFECTS OF TITANIUM DIBORİDE PARTICLE SIZE ON RADIATION SHIELDING PROPERTIES OF TITANIUM DIBORIDE REINFORCED BORON CARBIDE-SILICON CARBIDE COMPOSITES

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ABSTRACT

Composite materials have wide application areas in industry. Boron Carbide is an important material for nuclear technology. Silicon carbide is a candidate material in the first wall and blankets of fusion power plants. Titanium diboride reinforced boron carbide-silicon carbide composites which were produced from different titanium diboride particle sizes and ratios were studied for searching of the behaviour against the gamma ray. Cs-137 gamma radioisotope was used as gamma source in the experiments which has a single gamma-peak at 0.662 MeV. Gamma transmission technique was used for the measurements. The effects of titanium diboride particle size on radiation attenuation of titanium diboride reinforced boron carbide-silicon carbide composites were evaluated in related with gamma transmission and the results of the experiments were interpreted and compared with each other.

Key words: Nanocomposite, Boron Carbide, Titanium Diboride, Silicon Carbide, Cs-137 Gamma Source, Gamma Transmission Technique

INTRODUCTION

Boron carbide has wide application areas in industry. Some of these areas are nuclear technology, military industry, ceramic industry and air-space industry [1, 2]. Boron carbide has some important properties such as low-density, high hardness and corosion resistance, chemical stability and high neutron capture feature [2]. Some boron carbide application fields are lightweight ceramic armor, sand blasting nozzles, nuclear reactors, reactor control rods and the radiation shielding materials [2, 3]. However, boron carbide is brittle, has low strength and high temperature sintering properties [3, 4]. Sintering of pure boron carbide to high densities is difficult. So, specific additives such as SiC, TiB_2, AlF_3, elemental boron and carbon have been used as sintering aids to increase the density of composite [2-5].

Silicon carbide has been considered as a candidate material in the first wall and blankets of future fusion power plants because of its safety, environmental and economic benefits [6].

In this study, titanium diboride reinforced boron carbide- silicon carbide composites which were produced from different titanium diboride particle sizes and ratios were studied for searching of the behaviour against the gamma ray. For the investigation of

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the gamma radiation behaviour of these materials, Cs-137 radioisotope was used as gamma source in the experiments. Cs-137 gamma radioisotop source has a single gamma-peak at 0.662 MeV and its half life is 30.1y [7, 8]. Gamma transmission technique was used for the measurements.

Different titanium diboride particle sizes and ratios in titanium diboride reinforced boron carbide-silicon carbide composites were evaluated in related with gamma transmission and the results of the experiments were interpreted and compared with each other. Therefore, the effects of boron carbide particle size in titanium diboride reinforced boron carbide-silicon carbide composites on gamma radiation attenuation were investigated against Cs-137 gamma radioisotope source by using gamma transmission technique.

EXPERIMENTS AND MATERIALS

Gamma transmission technique is based on passing gamma rays through the materials. Detector and gamma source put both sides of the material. Detector material and gamma source are in the same axis. The gamma radiation counts are measured reaching to detector from the source. The counts with material and without material are compared and evaluate [7-9]. *Fig.1* shows schematic view of gamma transmission technique.

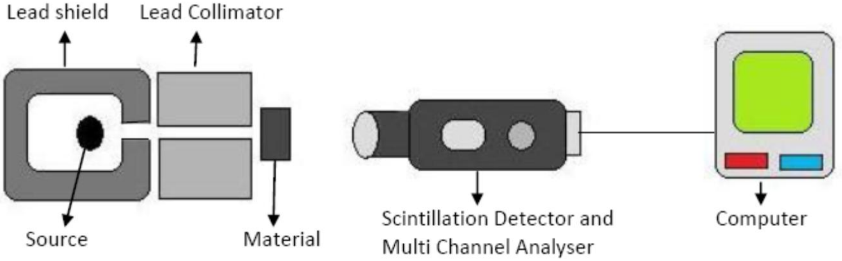

Fig. 1. Schematic View of Gamma Transmission Technique

The radiation passing through the material is calculated by the following equation: where I and I_0 are the transmitted and initial gamma ray intensities, respectively, μ is linear attenuation coefficient of material at specific γ- ray and x is the thickness of the material.

(1)

The materials which were used in the experiments have different boron carbide particle size ratios in the composites. Thus they are coded according to their boron carbide and titanium diboride ratios by volume in composites and particle size ratios. *Table 1* shows the materials that used in the experiments and their ratios by volume in the composite materials.

Table (1).The contents of the composite materials which were used in the experiments

Material (Code)	Boron Carbide (% Volume)	Silicon Carbide (% Volume)	Titanium Diboride (% Volume)	Nano Titanium Diboride (% Volume)
8202_b	78,4	19,6	2	-
8202_k	78,4	19,6	-	2
8204_b	76,8	19,2	4	-
8204_k	76,8	19,2	-	4

Table 2 shows the hardness, strength and density properties of the materials which were used in the experiments [5].

Table (2).The hardness, strength and density properties of the composite materials which were used in the experiments

Material (Code)	Strength (MPa)	Hardness (Vickers)	Density (g/cm^3)
8202_b	261,425±25,60	1902,57±131,8	2,361
8202_k	233,25±36,45	1868,29±96,74	2,394
8204_b	276,125±78,79	1983,67±56,78	2,429
8204_k	279,5±45,51	2211,80±168,17	2,476

For production of nano scale titanium diboride, titanium diboride materials were milled in Spex 8000 mill for one hour with WC balls. Average particle sizes were decreased to about 170 nm. Figure 2 shows particle size distribution graph of milled titanium diboride particles.

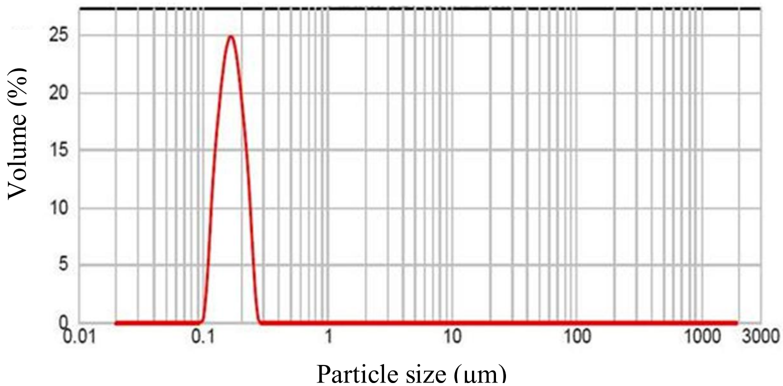

Fig 2. Particle Size Distribution of 60 minutes milled Boron Carbide

All composite materials were sintered hot pressed method at 2250 °C for 2 hours under 130 MPa pressure. Cs-137 Gamma Radiation source which has 8.9 µCi was used in the experiments. Lead blocks were used for radiation shielding and collimation. The collimator diameter is 7 mm. The distance between the detector and source is 10 cm.

Firstly background radiation measured. Then Cs-137 Gamma source was set. Initial intensity count (I_0) was measured. Then materials were set and intensity counts (I) were measured for different thickness values. All counts were measured three times for 600 seconds. Net counts calculated by reducing background value. Average values and standard deviations were calculated. For rational evaluating, relative intensity (I/I_0) values were calculated. Results were given with tables. Relative intensity-Material Thickness Graph was drawn for each Titanium diboride ratio and particle size. Exponential distribution was shown on graphs and exponential equations were calculated. Then results were evaluated and discussed.

RESULTS AND DISCUSSION

Results for 2% titanium diboride reinforced boron carbide-silicon carbide composites (8202_b) at different thicknesses with Cs-137 Gamma source are given on *Table 3*.

Table (3). Results for 8202_b titanium diboride reinforced boron carbide-silicon carbide composites with Cs-137 Gamma source

Background = 89			8202_b			
Thickness (cm)	**Net Count 1**	**Net Count 2**	**Net Count 3**	**Average Count**	**Standart Deviation**	**Relative Count**
0,000	8135	8128	8211	8158	46	1,000

0,590	7372	7393	7320	7362	38	0,902
1,165	6654	6652	6780	6695	73	0,821
1,725	6147	6121	6073	6114	37	0,749
2,287	5736	5689	5621	5682	58	0,696

Results for 2% nano titanium diboride reinforced boron carbide-silicon carbide composites (8202_b) at different thicknesses with Cs-137 Gamma source are given on *Table 4.*

Table (4). Results for 8202_k titanium diboride reinforced boron carbide-silicon carbide composites with Cs-137 Gamma source

Background = 89			8202_k			
Thickness (cm)	**Net Count 1**	**Net Count 2**	**Net Count 3**	**Average Count**	**Standart Deviation**	**Relative Count**
0	8081	8134	8096	8103	27	1,000
0,5879	7287	7280	7306	7291	13	0,900
1,1837	6630	6644	6640	6638	7	0,819
1,766	6090	6050	6071	6070	20	0,749
2,3512	5512	5538	5532	5527	13	0,682

Results for 4% titanium diboride reinforced boron carbide-silicon carbide composites (8204_b) at different thicknesses with Cs-137 Gamma source are given on *Table 3.*

Table (5). Results for 8204_b titanium diboride reinforced boron carbide-silicon carbide composites with Cs-137 Gamma source

Background = 89			8202_b			
Thickness (cm)	**Net Count 1**	**Net Count 2**	**Net Count 3**	**Average Count**	**Standart Deviation**	**Relative Count**
0,000	8135	8128	8116	8127	10	1,000
0,571	7346	7297	7367	7337	36	0,903
1,119	6718	6696	6725	6713	15	0,826
1,664	6163	6121	6171	6152	27	0,757
2,229	5610	5656	5590	5619	34	0,691

Results for 4% nano titanium diboride reinforced boron carbide-silicon carbide composites (8202_b) at different thicknesses with Cs-137 Gamma source are given on *Table 4*.

Table (6). Results for 8204_k titanium diboride reinforced boron carbide-silicon carbide composites with Cs-137 Gamma source

Background = 89			8202_k			
Thickness (cm)	**Net Count 1**	**Net Count 2**	**Net Count 3**	**Average Count**	**Standart Deviation**	**Relative Count**
0	8178	8093	8085	8118	52	1,000
0,5661	7266	7332	7382	7327	58	0,902
1,1332	6662	6658	6728	6683	40	0,823
1,7	5996	6184	6052	6077	96	0,749
2,27	5502	5572	5588	5554	46	0,684

Using the values on the tables Relative Intensity-Material Thickness Graphs were drawn for all titanium diboride reinforced boron carbide-silicon carbide composites. Exponential fitted equations were calculated. Figure 3 shows Relative Intensity-Material Thickness Graphs of 2% titanium diboride reinforced boron carbide-silicon carbide composites.

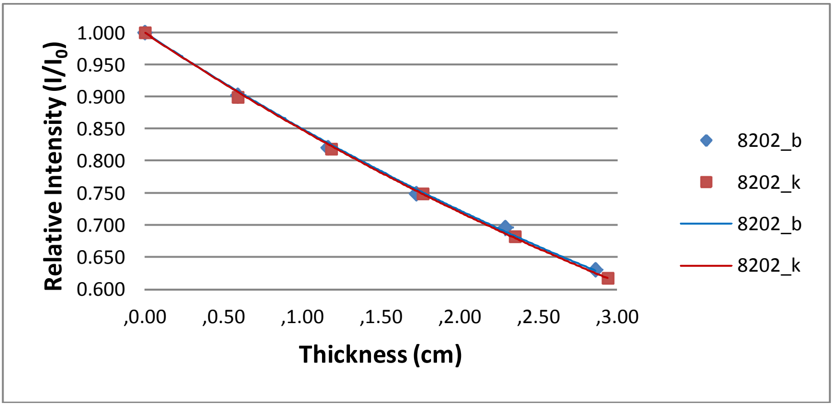

Fig. 3. Relative Intensity-Material Thickness Graphs of 2% titanium diboride reinforced boron carbide-silicon carbide composites.

Figure 4 shows Relative Intensity-Material Thickness Graphs of 4% titanium diboride reinforced boron carbide-silicon carbide composites

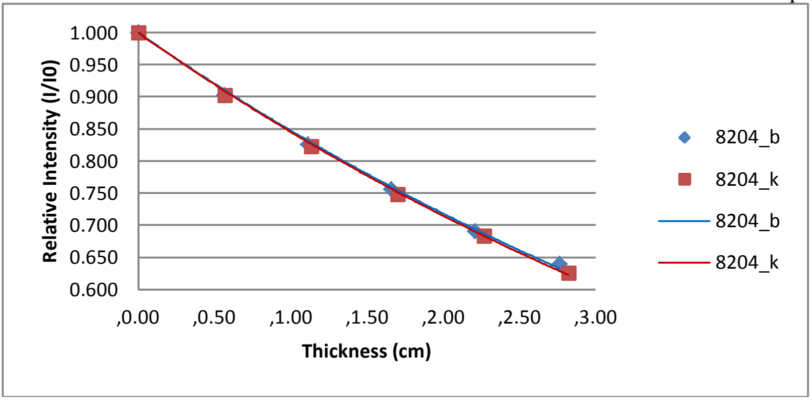

Fig. 4. Relative Intensity-Material Thickness Graphs of 4% titanium diboride reinforced boron carbide-silicon carbide composites.

Using the graphs on *Fig 3* and *Fig 4* the linear attenuations of the composite materials and correlation coefficients were calculated. The mass attenuation coefficients (μ/ρ) of the composite materials were also calculated. Then mass attenuation coefficient values were compared with the theoretical values which were taken from XCOM computer code.

The linear and mass attenuation values and XCOM values of the composites are given on *Table 6*.

Table (7). The Linear and Mass attenuation coefficient of the composite materials.

Material (Code)	Linear attenuation coefficient (cm^{-1})	Mass Attenuation Coefficient (cm^2/g) Experimental (10^{-2})	Theoretical (XCOM)	Difference (%)
8202_b	0,162	6,862	7,355	6,710
8202_k	0,164	6,850	7,355	6,867
8204_b	0,165	6,793	7,352	7,605
8204_k	0,168	6,785	7,352	7,712

All correlation coefficient values of the linear attenuation coefficients are over 0.99. The linear attenuation coefficients of milled titanium diboride reinforced boron carbide-silicon carbide composites are higher than unmilled reinforced ones. The mass attenuation values are closed to theoretical values which were taken from XCOM. The differences of theoretical and experimental values are between 6-8%.

CONCLUSIONS

It could be understood that for 2% milled titanium diboride reinforced boron carbide-silicon carbide, the linear attenuation coefficient is higher than unmilled one. In addition for 4% milled titanium diboride reinforced boron carbide-silicon carbide, the linear attenuation coefficient is higher than unmilled one the linear attenuation coefficient is higher than unmilled one . The experimental values and theoretical values from XCOM are closed to each other. Therefore it can be said that decreasing the titanium diboride particle size in the composites causes higher linear attenuation values.

In conclusion, milled composite materials are more convenient than unmilled composite materials for gamma radiation shielding in nuclear technology.

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