Determination of Mean Grain Size by Ultrasonic Methods of Tungsten Carbide and Boron Carbide Composites Sintered at Various Temperatures

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Abstract

In this study, the mean grain size of different ceramic-metal composites made from tungsten carbide and boron carbide, have been determined with ultrasonic velocity technique. In addition, electroless coating method was used to coat tungsten carbide samples. Prepared samples were sintered at the different temperatures ranging from 1200^{0}C to 1400 ^{0}C in an Argon atmosphere. Powders were placed in a 30mm diameter mold and pressed using a hydraulic press at a pressure of 200 bar.

The results were compared to the mean grain size obtained from SEM (Scanning Electron Microscopy). This study has shown a clear dependence of ultrasonic velocity on grain size in composites of boron carbide and tungsten carbide composite. Especially, temperature dependence of mean grain size for tungsten carbide composites can be seen very clearly.

Keywords: Ultrasonic, Composite, Grain size, Ultrasonic velocity.

1. Introduction

The ultrasonic wave propagation, for the determination of mean grain size of materials has been considered by several researchers with various techniques, such as ultrasonic velocity [1,2], ultrasonic backscatter [3-5], ultrasonic attenuation [6-8] and ultrasonic relative attenuation [9]. In these methods, ultrasonic velocity and ultrasonic attenuation techniques have advantages in means of simplicity, required instrumentation and wide range of materials.

Composite materials are also divided in two main parts, metal matrix and ceramic-metal composites. In this study, boron carbide and tungsten carbide ceramic-metal composite samples have been used to determine their grain size by using ultrasonic velocity technique.

Hirsekorn [10,11] has explained relation between ultrasonic velocity and grain size. According to Hirsekorn, in the Rayleigh scattering region, longitudinal and transverse ultrasonic wave velocities have been given as a function of wave number, *k* and the grain radius, *a*. For a longitudinal wave, phase and group velocities are given as,

$$v_{LP} = v_L \left\{ 1 + \left(\frac{\phi}{\rho_o v_L^2} \right)^2 \frac{2}{3 \cdot 5^3 \cdot 7} \left[14 + 21 \frac{\kappa^2}{k^2} + \frac{2}{5} \left(\frac{106}{7} + \frac{6}{7} \frac{\kappa^2}{k^2} + 21 \frac{\kappa^4}{k^4} \right) (ka)^2 \right] \right\}^{-1} \qquad (1)$$

$$v_{LG} = v_L \left\{ 1 + \left(\frac{\phi}{\rho_o v_L^2} \right)^2 \frac{2}{3 \cdot 5^3 \cdot 7} \left[14 + 21 \frac{\kappa^2}{k^2} + \frac{6}{5} \left(\frac{106}{7} + \frac{6}{7} \frac{\kappa^2}{k^2} + 21 \frac{\kappa^4}{k^4} \right) (ka)^2 \right] \right\}^{-1} \quad (2)$$

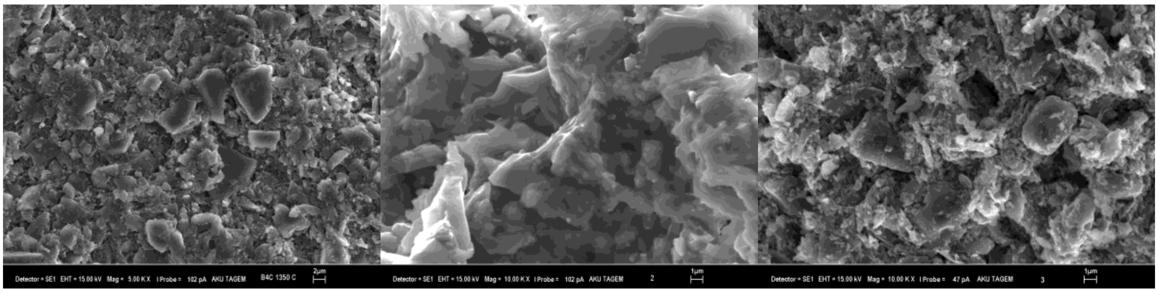
where ϕ is the anisotropy factor, κ and k are the wave numbers and a is the grain radius. Experimental work of these relations has been reported in [9].

2. Samples

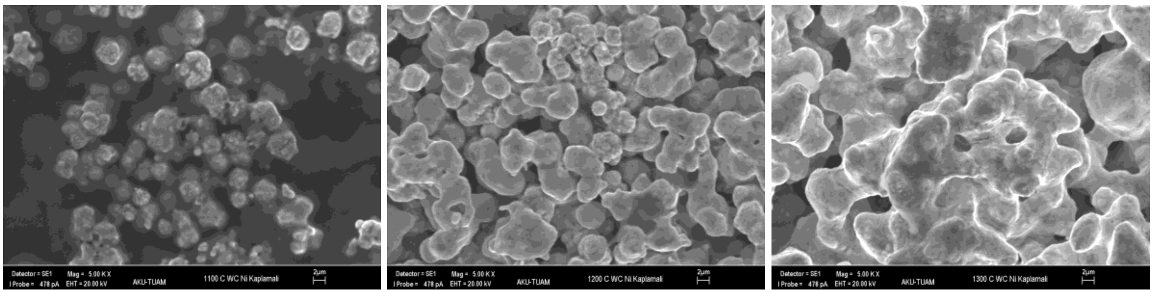
In this work, two different methods have been used for sample preparation. Samples, based on Boron carbide have been prepared by powder metallurgy. Powders have been mixed and hydraulically pressed at a pressure of 200 bar in a 32.8 mm diameter mold. Then, these samples were sintered at temperatures of 1200, 1300 and 1350°C in an Ar gas atmosphere in a tube furnace.

Samples, based on Tungsten carbide have been prepared by using electroless plating [12]. According to this method, tungsten carbide powder has been plated by nickel using electroless plating and hydraulically pressed at a pressure of 200 bar in a 30.0 mm diameter mold and sintered at temperatures of 100, 1200 and 1300°C in an Ar gas atmosphere in a tube furnace.

Sintered specimens were characterized using Leo 1430 VP scanning electron microscopy at Afyonkarahisar Kocatepe University, Technical Application and Research Center. Figure 1 shows SEM images of samples.



(a) (b) (c)



(d) (e)

Figure 1. SEM images of samples, (a) B_4C at 1350°C, (b) B_4C+Al at 1350°C, (c) B_4C+Al+Ni at 12000°C, (d) WC-Ni at 1100°C, (e) WC-Ni at 1200°C and (f) WC-Ni at 1300°C.

3. Ultrasonic Measurements

Ultrasonic velocity measurements have been realized in TUBITAK, Marmara Research Center by using Krautkramer, USN52L flaw detector. Velocity values of 2 and 4 MHz T/R transducers have been obtained directly from a property of detector. Figure 2, shows flaw detector and velocity measurement screen.

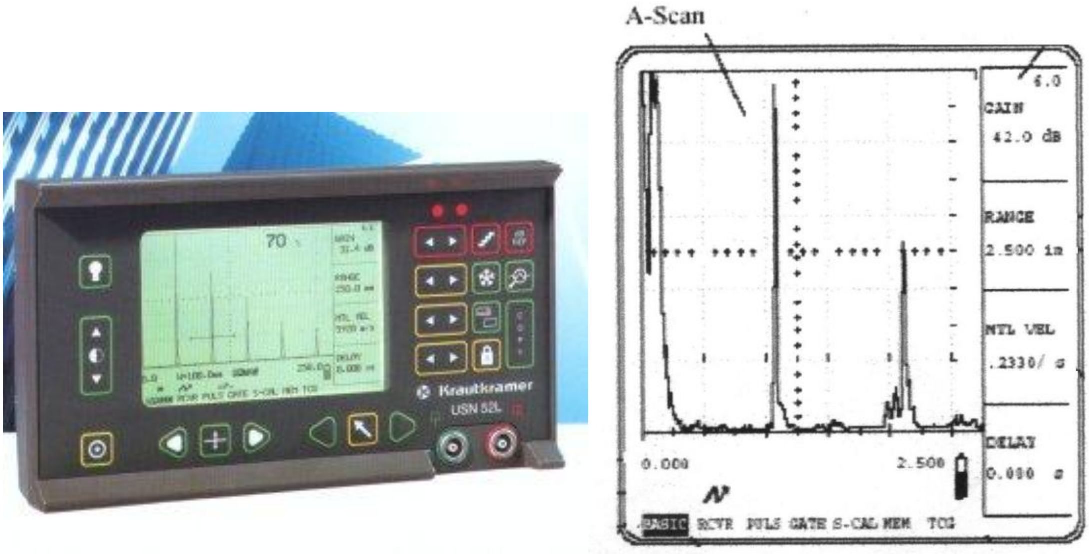


Figure 2. Flaw detector and velocity measurement screen.

4. Results

The mean grain size of samples has been calculated by analyzing the contrast difference of the particles in the images. The results are given in Table 1. Longitudinal ultrasonic velocity values of samples are given in Table 2.

Table 1. The grain size of samples determined from SEM images

Sample	Material	T_S (°C)	Mean Grain Size (µm)
1	B_4C	1350	19.3
2	B_4C	1350	18.3
3	B_4C+Al	1350	32.5
4	B_4C+Al+Ni	1300	20.9
5	B_4C+Al+Ni	1350	20.1
6	B_4C +Al+Ni	1200	19.2
7	WC-Ni	1100	3.54
8	WC-Ni	1200	3.92
9	WC-Ni	1300	5.19

Table 2. Ultrasonic velocity values of samples by 4 MHz probe.

Sample	Material	Velocity (m/s)
1	B_4C	2410
2	B_4C	2135
3	B_4C+Al	7470
4	B_4C+Al+Ni	3475
5	B_4C+Al+Ni	2970
6	B_4C+Al+Ni	2770
7	WC-Ni	2516
8	WC-Ni	2586
9	WC-Ni	3181

We have graphed the given results in two different graphs, Figure 3 and Figure 4. Since, base elements are different we have not presented them in the same graph. As can be seen from the graphs, mean grain sizes of samples versus longitudinal ultrasonic velocities are linearly correlated (for the boron carbide samples graph's R^2 value is 0.991 and tungsten carbide samples graph's is 0.984).

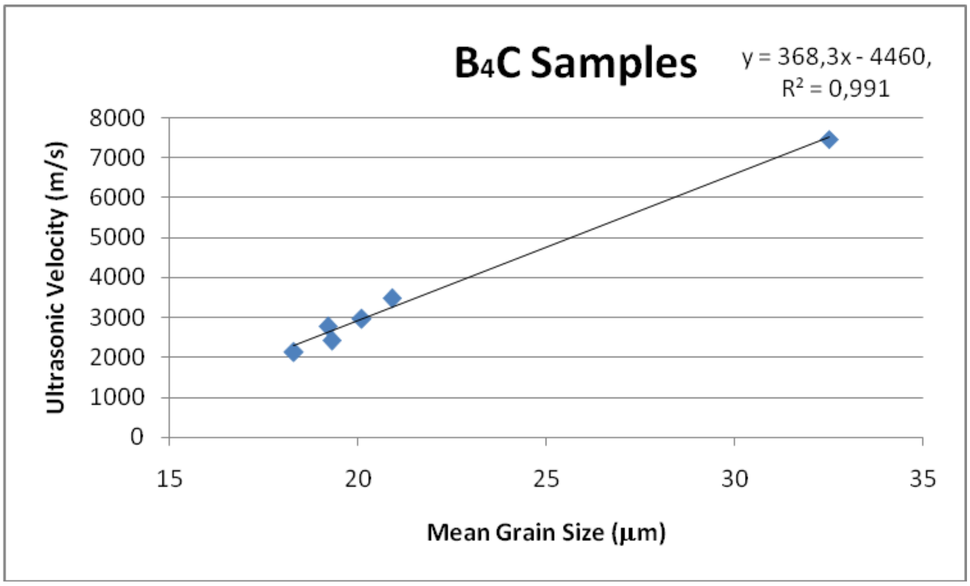


Figure 3. Ultrasonic velocity – mean grain size graph of B_4C based composite samples.

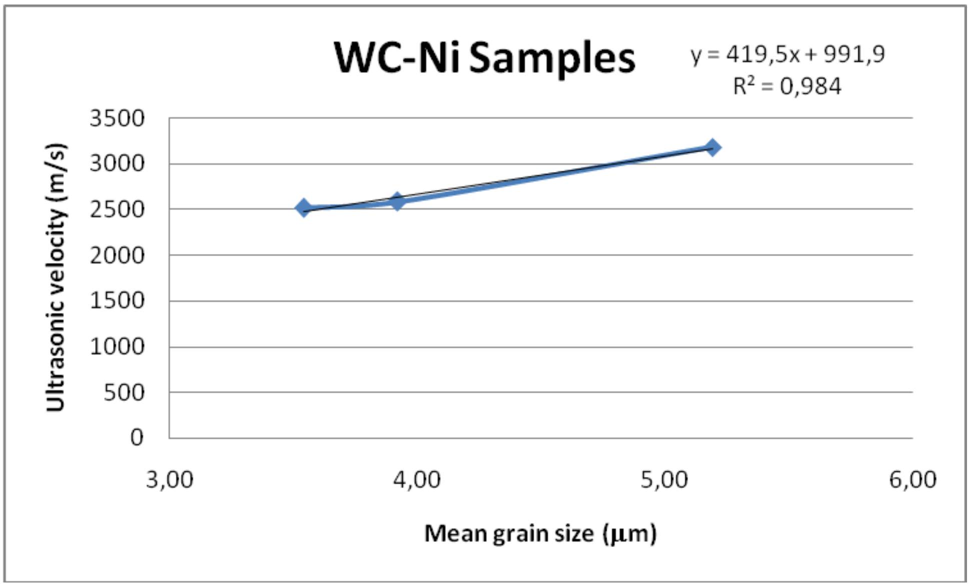


Figure 4. Ultrasonic velocity – mean grain size graph of WC based composite samples.

5. Conclusion

This study has shown a clear dependence of ultrasonic velocity on grain size in composites of boron carbide and tungsten carbide composite. Especially, temperature dependence of mean grain size for tungsten carbide composites can be seen very clearly.

6. Acknowledgements

The authors are grateful to TUBITAK, Marmara Research Center and Afyonkarahisar Kocatepe University, Technical Application and Research Center for their help in experimental work. This work has been supported by

Afyonkarahisar Kocatepe University Research Grant number 06.FENED.11.

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