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Study of Fracture Toughness in B_4C-TiB_2 Nanocomposites with Vickers Indentation Test Method at Different Loads

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ABSTRACT

According to widespread and increasing efficiency of ceramics in different industries, identification their mechanical properties with minimum time and cost is important for the optimal design. Unique properties of boron carbide (B_4C) such as high hardness, low density, and comprehensive area for notron attraction, have turned this material into a very suitable candidate for many industrial applications such as nuclear facilities and light armored plates. In this paper, B_4C nanocomposite samples with a volume of 10% of TiB_2 were prepared and the values of density, hardness and Elasticity modulus were determined and then the fracture toughness values were calculated by using various fracture toughness formula with Vickers indentation test method in loads of 100N and 150N and their results were compared to each other. The results show that the modified equation with using cracks leads high accuracy and efficiency compared to other relations. It also concluded that the growth mechanism due to different loads affects on the results of fracture toughness values.

KEYWORDS

Fracture Toughness, Nanocomposite, Indentation Method, Titanium Diboride, Boron Carbide.

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1- INTRODUCTION

So far, many methods have been employed to determine the fracture toughness of the materials while they are generally very expensive. One of the ways to determine the fracture toughness of brittle materials in the past three decades is based on the crack surfaces caused by indentation method. In this method, making test samples is very simple and determination of the toughness of materials is easy and fast. Many researchers have been investigating in this field. For the first time, Palmqvist [1] introduced and developed the Vickers indentation technique. Then , Anstis et al [2] developed this technique for many brittle materials and found a popular and applicable formula. Many equations , which determine the fracture toughness of brittle materials using this method , are classified in four categories by the authors of this paper [3]; Palmqvist's equations, median cracks, curve fitting technique and fracture toughness equation resulting from the surface cracks. These classifications are based on the values of brittleness of the materials, crack growth mechanism, loading and the accuracy of the results. In this research, the fracture toughness of nanocomposites B_4C-NanoTiB_2 is determined by Vickers indentation test experimentally and the results are compared with the output values of these equations.

The loading process in Vickers indentation method has an important role in determining the fracture toughness. Furthermore, gradually applied load leads to an increase in the results of equations. It is shown that the fracture toughness of B_4C is increased 28% by adding 10 volume percent of TiB_2. Likewise , variation in loading causes large fluctuations in the results of fracture toughness values obtained from different equations of B_4C-NanoTiB_2.

2- METADOLOGY

In this study, a volume of 10% of TiB2 nanocomposite powders was used which is prepared by sol - gel method in combination with B4C. This nanocomposite powder contains 2 volume percent of carbon, as an additive. Method of preparation of the samples is based on the research activities carried out by Moradkhani et al [4 and 5]. In this method, after weighing the raw materials by a digital scale, raw materials were mixed by planetary mill in isopropanol for 2 hours with 150 rpm. After milling, grout was vaporized by the means of heater followed by heating in oven at 110 ºC for 24 hours. After sifting the powder and obtaining the uniform particle size, they were formed in cylindrical parts with the diameter of ½ cm and height of 1 cm by hydraulic press at 80 MPa pressure. Then , the cylindrical specimens were sintered at 2225 °C by hot-press method in argon, for an hour. After polishing the specimens, Vickers indentation method was used to determine the fracture toughness and mechanical properties of specimens.

The density and porosity of the specimens were measured using the Archimedes method. The elastic modulus of the specimens was determined according to ASTM C769. Hardness determination of the specimens was done with the Vickers method and according to ASTM C1327. The results show that by adding a volume of 10% TiB2, the fracture toughness of specimens is increased significantly compared with the samples without additives. It is also concluded that output values of the fracture toughness equations change significantly by different loading.

3- RESULTS AND DISCUSSIONS

Figure 1 represents the values obtained by / through different equations of Vickers indentation tests on the samples with a load of 100 N and 150 N. As the figure shows , the change in the fracture toughness is tangible for each equation. Figures 2 and 3 illustrate the effect of Vickers test on some specimens in loads of 100N and 150N.

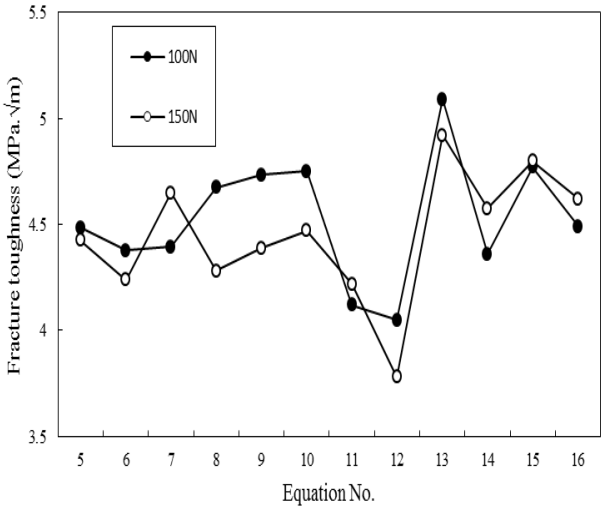

Figure 1: the values of fracture toughness of B4C-NanoTiB2

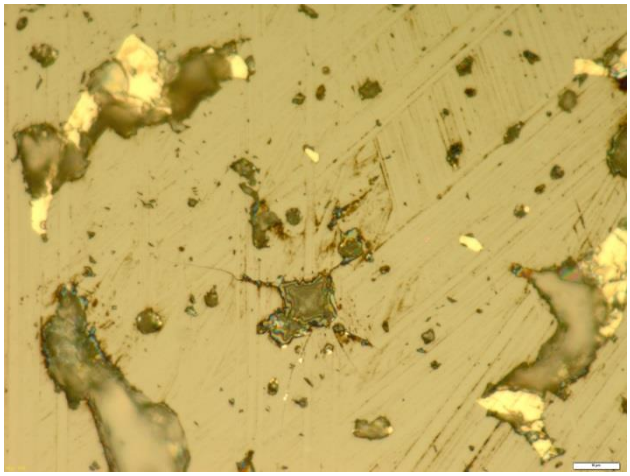

Figure 2: the effect of Vickers test on the sample in load of 100N

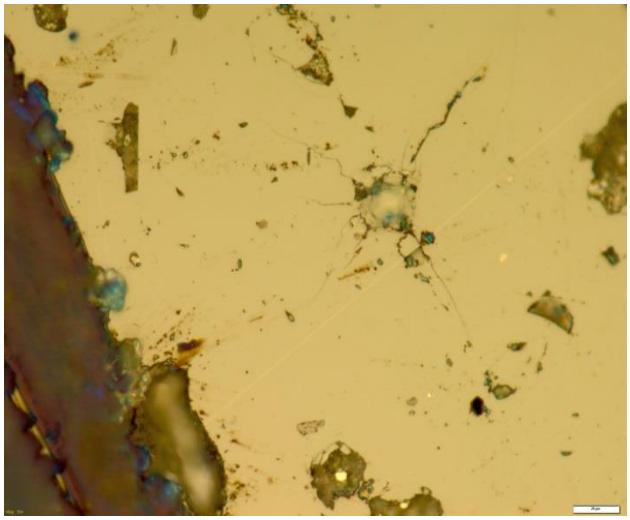

Figure 3: the effect of Vickers test on the sample in load of 150N

4- CONCLUSION

This research investigated the influence of crack growth in the various loads of B4C–NanoTiB2 nanocomposites. The following results can be noted:

- The values of density, Elasticity modulus and hardness were obtained 2.61gr/cm3, 485.343GPa and 33GPa, respectively.
- The fracture toughness value obtained 4.54 $MPa.m^{1/2}$ and the results obtained by the derived equation have acceptable accuracy compared to the results of other relations.
- By adding 10vol% titanium diboride to B_4C, the fracture toughness of this ceramic was increased to 28%.

5- REFERENCES

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