The Oxidation Effect on The Reinforcement Particles of Al / B_4C Metal Matrix Composite

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1. Introduction

Finding proper neutron absorber materials for spent fuel storage and transport is one of the biggest challenges of nuclear engineering. One of the promising neutron absorber materials for storage and transportation of spent fuel is B_4C because of its high neutron absorption cross section [1]. However, B_4C is ceramic, which means it has low ductility and machinability. Therefore, the fabrication of metal matrix composite (MMC) containing B_4C is one solution to the problem associated with the ceramic characteristic of B_4C.

However, boron carbide has a high interfacial energy with aluminum and also produces aluminum carbide, which is detrimental compound, through a chemical reaction, so there is a limit to making MMC [2].

In the case of SiC, another well-known carbide reinforcement, there have been many attempts to oxidize the surface to lower the interfacial energy and inhibit the formation of aluminum carbide [3-4]. However, in the case of boron carbide powder, oxidation occurs at a temperature higher than the melting point of boron oxide, which is an oxidized product, so, powder agglomeration occurs during the oxidation process. So far, no research has been done to oxidize the surface of boron carbide to produce high-quality MMC.

In this study, low-temperature oxidation was performed to overcome the agglomeration due to powder oxidation. MMC was made with surface oxidized boron carbide to compare mechanical properties, hardness, and flexural strength with untreated MMC.

2. Experimental procedure

2.1 Sample preparation

The fabrication procedure of MMC consists of the following steps. First, B4C particles of 3.5 μm and 40 μm in diameter were oxidized in an air environment at a temperature of 600℃ for 1, 2, and 3 hours. Then, Oxidized and non-oxidized powders are mixed with aluminum powder (ECKA 231D) in a 2: 8 ratio for 300 minutes using a 3D mixer at 40 rpm.

The mixtures were pressurized at 50 MPa for sintering in a spark plasma sintering machine, heated to 450℃ for 5 minutes and held for 5 minutes.

2.2 Hardness test

The surface of oxidized and non-oxidized MMC prepared for hardness test was polished to 2000grit using SiC polishing paper. The hardness was then measured through a Rockwell B scale hardness tester.

2.3 Bending test

For the bending test, the sintered samples were cut to a size of 2.7 * 2.0 * 11 cubic mm. Then, the flexural test was performed using a universal testing machine (UTM, Instron 5583, Instron Corporation, USA). At this time, the test was performed following ASTM C1421 – 10.

2.4 Microstructure

The dispersion of the reinforcement and the microstructure of the specimen were observed with a scanning electron microscope (SEM). To determine the mode of failure of the material, the fracture surface after the bending test was also observed with SEM.

3. Result

3.1 Hardness test

Although no investigation has been done on the value of MMC containing B_4C, it is predicted that the hardness value will be improved by a study of the SiC reinforced MMC, which is a previous study of this researcher (Fig. 1)

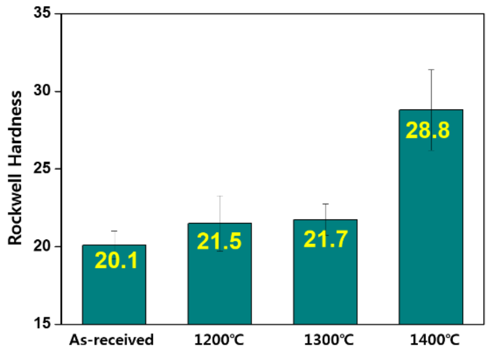

Fig. 1. Hardness data of surface-oxidized SiC / Al MMC.

In the SiC data, the oxidation temperature is variable, but in this experiment, the oxidation time of B_4C is the variable.

3.2 Bending test

The bending test has not yet been carried out, but according to previous experimental results (Fig. 2), a coherent interface is formed when B_4C is coated. Therefore, high Young's modulus and fracture toughness are expected in the case of oxidized MMC.

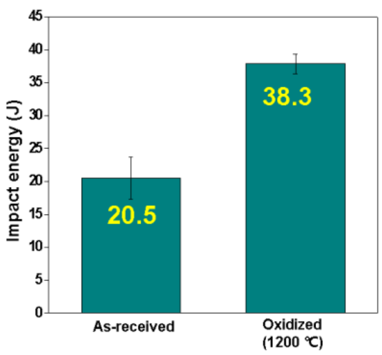

Fig. 2. Impact resistance data of surface treated B_4C and non-treated B_4C reinforced MMC.

3.3 Microstructure

The microstructure has not yet been observed, but according to existing data, the oxidized B_4C reinforced MMC will show a more dense and less porosity microstructure.

4. Conclusion

In this study, B_4C powder, which is difficult to oxidize the surface, was oxidized without agglomeration at low temperature. By doing this coating, Al / Oxidized B_4C MMC, which has not been studied previously, is prepared. As a result, the mechanical properties of the B_4C reinforced Al-based MMC were increased by the surface oxidation treatment as in the other typical carbide materials SiC.

The B_4C oxidation coating lowers the interfacial energy with aluminum and also inhibits the chemical reaction. This allowed the microstructure to produce sound MMC. Due to the sound microstructure, hardness increased and fracture toughness increased.

This result can be used for all B_4C / Al MMC applications and especially can be used as a neutron absorber, in nuclear applications where safety and robust are important.

Acknowledgments

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