Preparation of 6061 Borated Al alloy by hot isostatic pressing (HIP)

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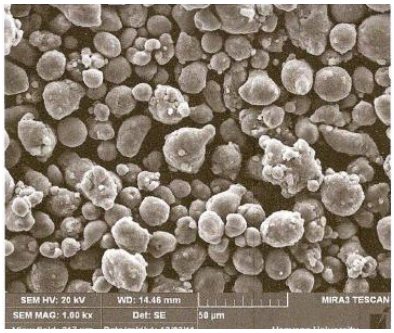
1. Introduction

Neutron absorber for wet/dry spent fuel storage applications are used in plate or sheet form. Neutron absorber materials are comprised of a chemical form of the neutron absorber nuclide and a matrix that serve to hold the absorber nuclide in its intended location[1]. Of the metal matrix neutron absorbers, aluminum has been the most commonly used although stainless steel is another choice that has been used, extensively. Aluminum (Al) matrix absorbers can be manufactured to generally thin plate form by a variety of methods[2-3]. In one method, a preform with near maximum theoretical density can be produced by casting and hot rolling. In another, aluminum and boron carbide with a full dense is produced using powder metallurgy technology. This is well known as metal matrix composites (MMCs) such as BORAL. This material is prepared by hot rolling a cubic aluminum ingot containing powdered aluminum and boron carbide. Discontinuously reinforced aluminum /boron carbide (B_4C) composite like a cermet offer a product with superior mechanical properties relative to the aluminum alloys itself. However, the density of this cermet is less than 100 % dense due to some internal porosity in MMCs. The hot isostatic pressing (HIP) is a candidate to get full density. In this study, MMCs of aluminum and boron carbide were prepared by powder mixing and canning HIP process. The density of prepared plate were measured by using gas pycnometer method, and compared to MMCs produced by METAMIC Co.

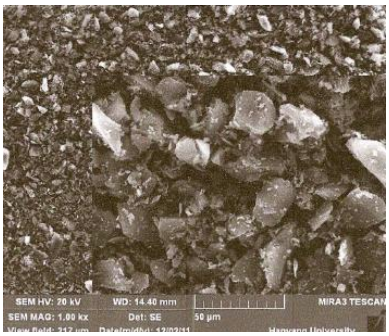
2. Methods and Results

2.1 Materials Preparation

The plates (or sheet) of neutron absorber were prepared by using micro-B_4C dispersed Al composites. Prior to fabricate the composites, B_4C (~10 μm, Kojundo Chem., Japan) and Al powder were prepared by shaking using powder mixer. Figure 1 shows the SEM images of B_4C and Al particles used in the experiment. As shown in the images, average size of the nano-B_4C and Al powders were 10 μm and 20 μm respectively. Raw materials were blend by powder mixer, and put into the stainless steel can to carry out dense compaction. Mixed B_4C and Al powders in can were then pressed isostatically under 100 MPa of chamber pressure and Ar gas atmosphere. The maximum temperature and maintenance time were up to 590 ℃ and for 1 h, respectively. The time dependent on HIP treatment condition was illustrated in Fig. 2.



(a)



(b)

Figure 1 SEM images of the (a) B_4C particles and (b) Al particles.

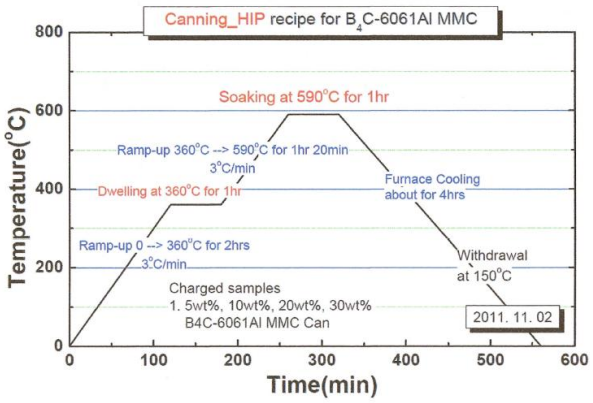


Figure 2 HIP treatment conditions for neutron absorber materials.

2.2 Materials Properties

The density of prepared sheet by HIP process as a function of B_4C concentration is complied in Table 1. The density was measured by using gas pycnometer. The formation of fully dense plates without internal porosity was conformed, as comparing to density of MMCs produced by METAMIC. The prepared cermets by HIP show higher areal density than those of commercial product. As the concentration of B_4C is increased, the density is decreased.

Table 1 As a function of B_4C loading density for neutron absorbers of both commercial product and cermets prepared by HIP process.

B_4C (wt.%)	Density of MMCs prepared by HIP (g/cm^3)	Density of MMCs produced by METAMIC (g/cm^3)
0	2.7562	-
5	2.7044	2.691
10	2.6983	2.682
20	2.6826	2.664
30	2.6684	2.646
100	2.5900	-

2.3 Neutron Shielding Tests

Neutron shielding tests for prepared neutron absorber were performed by using thermal neutron source (energy ~0.025 eV) in HANARO reactor. The neutron flux was up to 6×10^5 $n/cm^2/sec$. The University of Michigan performed an extensive study of neutron transmission through BORAL for various ^{10}B loading, sheet thickness, particle size, and neutron energy[4]. The size effect for the neutron shielding was investigated, experimentally. The particle diameter of the born, neutron absorber, affect to thermal neutron absorption. The smaller diameters of B were reinforced in matrix, the higher neutron absorption cross section was look forwarded[4]. Figure 3 show the macroscopic thermal neutron attenuation as a function of the concentration of B_4C with different boron diameters in the sheet. Indeed, the small particle size affect to positive results. However, the size effect shows the saturation phenomena. The thermal neutron absorption cross section ($\sum_{th}$) for the 5 wt.% -B_4C dispersed Al matrix prepared by HIP was 2.48 cm^{-1} at sheet thickness of 2 cm. The range of particle size for raw material of B_4C was from 2 to 10 μm. The thermal neutron attenuation for the MMCs prepared by HIP show similar result as nanoparticles (~ 500 nm) dispersed cermet.

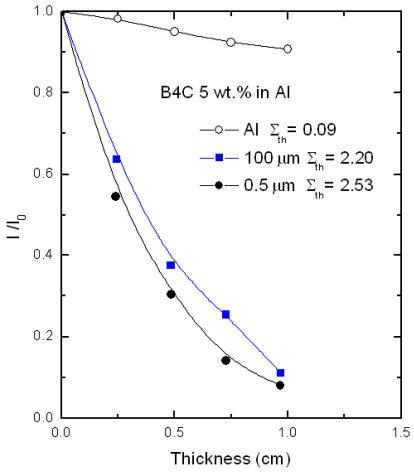


Figure 3. Neutron attenuation for the different size B_4C reinforced MMCs

3. Conclusions

The plates (or sheet) for neutron absorber of B_4C dispersed Al composites were prepared by using HIP process. The densities of prepared sheets as a function of B_4C concentration were measured by using gas pycnometer. The formation of fully dense plates without internal porosity was conformed, as comparing to densities of MMCs produced by METAMIC. The prepared cermets by HIP show higher areal density than those of commercial product. As the concentration of B_4C is increased, the density is decreased.

The boron particles with small size affect to the enhancement of thermal neutron shielding efficiency. However, the size effect for thermal neutron shielding is saturated below several micrometers.

Acknowledgement

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