PREPARATION OF SANDWICH STRUCTURE AND FUNCTIONALLY GRADED Al/SiC$_p$ COMPOSITES

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Abstract

A simple and low-cost processing route for the preparation of sandwich structure (SS) and functionally graded (FG) Al/SiC$_p$ composites by pressureless infiltration has been developed. Three-layer composites were prepared by the non-assisted infiltration of plate-shaped SiC$_p$ porous preforms by an experimental Al-Si-Mg alloy. The sandwich structure type and graded plate composites were characterized by X-ray diffraction (XRD) and scanning electron microcopy (SEM) in addition to hardness tests, which ultimately depict the SS and FG nature of the composites. The results show that by a suitable selection of the processing parameters it is possible to produce SS and FG Al/SiC$_p$ composites via pressureless infiltration.

Introduction

To date the pressureless infiltration method has been used mostly for the preparation of monolithic Al/SiC$_p$ composites, with a single particle size distribution of reinforcements and ceramic volume fraction. Only a few works regarding the use of layers have been published [1, 2]. And due to its capillarity dependent nature, the challenge has often been to achieve a full wetting of the solid reinforcements by the liquid metal [3, 4]. It can readily be recognized that when there exists an interface formed by two preforms with different characteristics (vol. fraction of reinforcements or porosity, particle size, thickness, etc.) the capillary conditions change from one to another and different degrees of infiltration can be obtained. The difficulty increases, moreover, when more than two preforms are piled up. The failure is manifested typically by the presence of porosity, which can be classed in alloy matrix porosity and lack of filling, observed as inter-particle holes. Essentially the problem lies on the changes in capillary pressure – usually denoted as ΔP – caused by the differences in preform characteristics. Therefore, if it is wanted to infiltrate the preform assembly in one-step, then it is highly recommended to conduct infiltration optimization tests. Interestingly, the assembly of plate preforms with different characteristics can exhibit a sandwich structure type or a functionally graded feature, manifested by the physical and mechanical properties of each layer. Furthermore, one can benefit form these characteristics for the manufacture of components for a variety of applications, such as armor plates. In this contribution the authors propose a simple route for the preparation of SS type and FG Al/SiC$_p$ composites at laboratory scale.

Experimental procedures

Plate-shaped (3 cm x 4 cm) porous preforms with different thicknesses (0.3, 0.5 and 0.7 cm) were prepared by the uniaxial compaction of SiC and SiO_2 powders. The SiC powders were used in two particle sizes, 20 and 75 µm, while silica was used in 300 µm, respectively. Both types of powders were properly mixed in a porcelain mortar with distilled water and 5 wt.% dextrin. Then, the mixture was compacted in a plate-shaped steel mold using a load of 2 Tons. Subsequently the preforms were dried in a furnace at 120 ^oC for two hours to eliminate the water, and then treated thermally at 225 ^oC for other two hours to partially eliminate the dextrin. Based on the predetermined amounts of SiC and SiO_2, preforms with 40, 50 and 60 % porosity were prepared.

Infiltration trials were performed in a horizontal tube furnace with a 6.5 cm diameter alumina tube closed at both ends with end-cap fittings to control the process atmosphere. A K-type thermocouple was inserted in one end of the tube to control the sample temperature. The mold-preform-metal assembly was placed in the center of the alumina tube and heated either in ultra high purity Ar atmosphere at a rate of 15°C/min up to the test temperature (1050, 1100 and 1150 ^oC). After furnace cooling to room temperature, the specimens were removed for characterization using X-ray diffraction (Cu-K_α radiation) and the microstructure was analyzed by SEM and EDX. The plates were also tested in Rockwell B surface hardness measurements. Five to ten indentations were performed in each layer.

Results and discussion

Results from the characterization by X-ray diffractions show that in addition to SiC, Al and Si, magnesium silicide (Mg_2Si) and magnesium aluminate spinel ($MgAl_2O_4$) were also detected. Spinel is formed by the reaction of SiO_2 with Al and Mg in liquid the alloy. Spinel formation has a particular relevance, as it is a means for preventing the attack of SiC by liquid aluminum and the subsequent formation of the deleterious Al_4C_3 phase.

Characterization by optical and scanning electron microscopy suggests that within each layer there is a uniform distribution of the SiC particulate reinforcements. Moreover, there is also evidence of the soundness of the reinforcements because they weren't attacked by the liquid aluminum alloy. In other words, spinel formation successfully fulfilled its work. Figure 1 shows an optical photomicrograph of a three-layer composite.

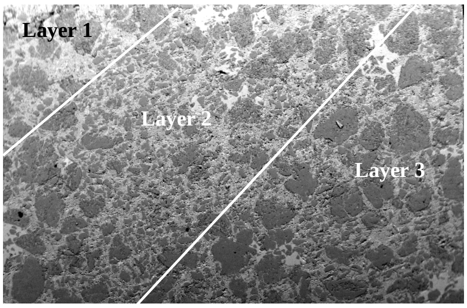

Fig. 1 Optical photomicrograph of a three-layer composite.

Figure 2 shows a typical FG Al/SiC$_p$ composite, with Hardness values increasing gradually from 70 to 91.4 Rockwel B hardness values in a linear fashion.

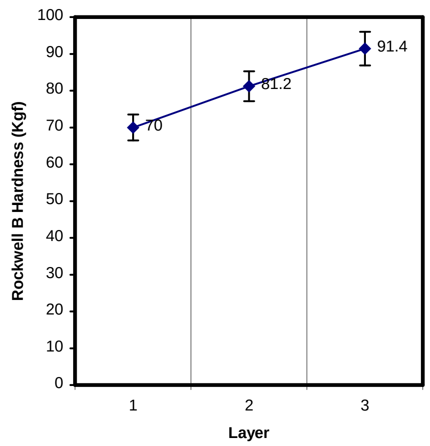

Fig. 2 Typical functionally graded three-layer composite.

Figures 3 and 4 are typical hardness graphs of sandwich structure composites. Proper selection of the preform processing parameters allows obtaining a sandwich structure with a core-layer with lower or higher hardness, compared to the cover layers.

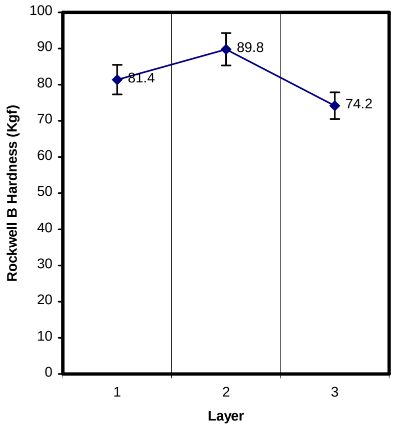

Fig. 3 Typical sandwich structure Al/SiC composite.

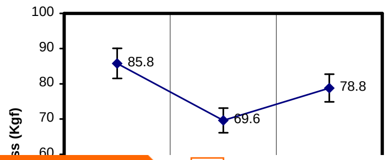

Fig. 4 Typical sandwich structure Al/SiC composite.

The hardness behavior observed is ascribed essentially to the preform characteristics. And as it may be recalled, the preforms may differ either in percent porosity or in SiC particle size. Given the potential of the proposed method to prepare three-layer composites and the need to identify them, in this work, authors provide with a nomenclature to designate the composites, namely, sandwich structures with a harder core are referred to as HCSS while those with a softer core than the outer layers are denoted as SCSS.

Summary and conclusions

It has been shown that the pressureless infiltration method can successfully be applied for the preparation of three-layer Al/SiC$_p$ composites featuring functionally graded or sandwich structure attributes. These characteristics are evidenced through the increase or decrease in superficial hardness within each layer (FG) or by the increase-decrease-increase or decrease-increase-decrease hardness behavior (SS). Further characterization of the composites would include Charpy impact tests and fracture surface analysis.

References

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