Impact of Porosity and Clustering on Properties of AA1100/B_4C Nanoparticle-Reinforced Metal Matrix Composites

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ABSTRACT

Aluminum alloys reinforced with particulates are more attractive than traditional aluminum alloys for applications requiring higher stiffness and strength. Stir casting route is the most promising one for synthesizing discontinuous reinforcement dispersed aluminum alloy matrix composites because of its relative simplicity and easy adaptability with all shape casting processes. The composites produced by stir casting have many defects such as particles clustering and high porosity content, which have a deleterious effect on the mechanical properties. In cast metal-matrix composites, particle clustering (figure 1) is due to the combined effect of reinforcement settling and the rejection of the reinforcement particles by the matrix dendrites while these are growing into the remaining liquid during solidification.

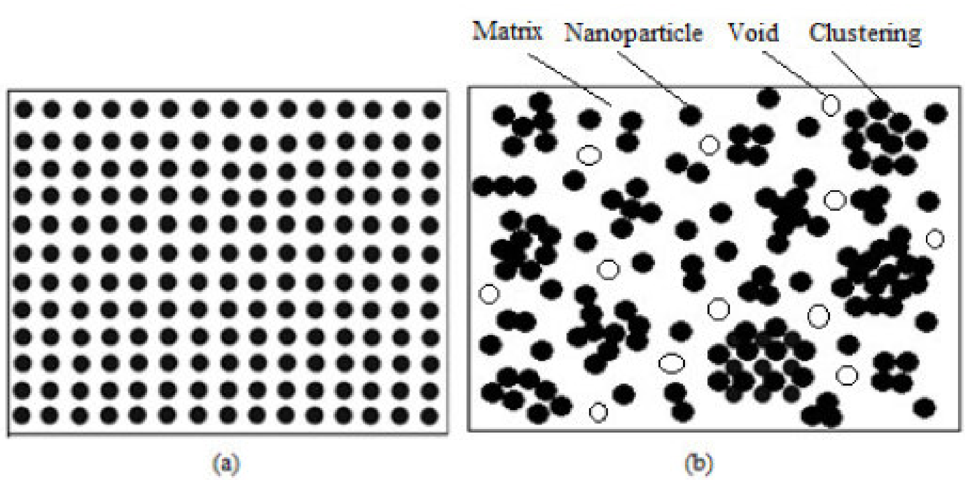

Figure 1: Distribution of particles: (a) without voids and clustering and (b) with voids and clustering.

The objective of this paper is to study the effect of particle clustering and porosity on micromechanical behavior using experimental procedure and finite element method (FEM). Two models were used in the computational framework. The first one is uniform distribution of nanoparticles without clustering and porosity. The second one is with clustering and porosity.

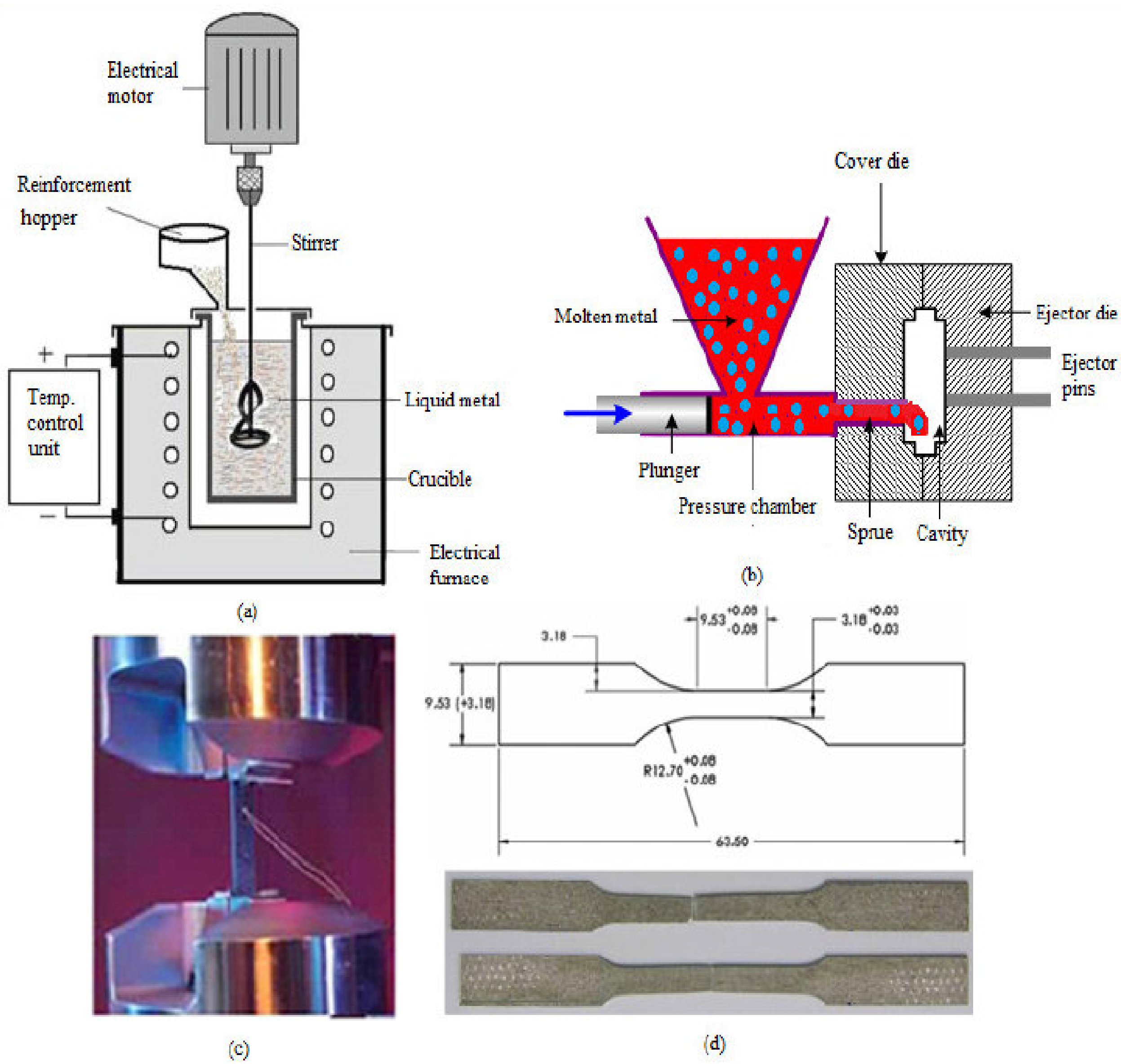

Figure 2: Fabrication and testing of composites: (a) stir casting process, (b) high pressure die casting, (c) tensile testing and (d) tensile specimens.

AA1100/B_4C metal matrix composite produced presented a larger number of clusters and a few voids due to high pressure die casting process. The voids are typically located at the interface of clustered particles. The cracks clearly emanate from the voids and clustered regions. The rate of strength decrease with porosity and clustering of nanoparticles was analyzed for tensile strength for three volume fractions of boron carbide nanoparticles in AA1100 alloy matrix. The strength degradations were generally within the range of data reported in the literature.

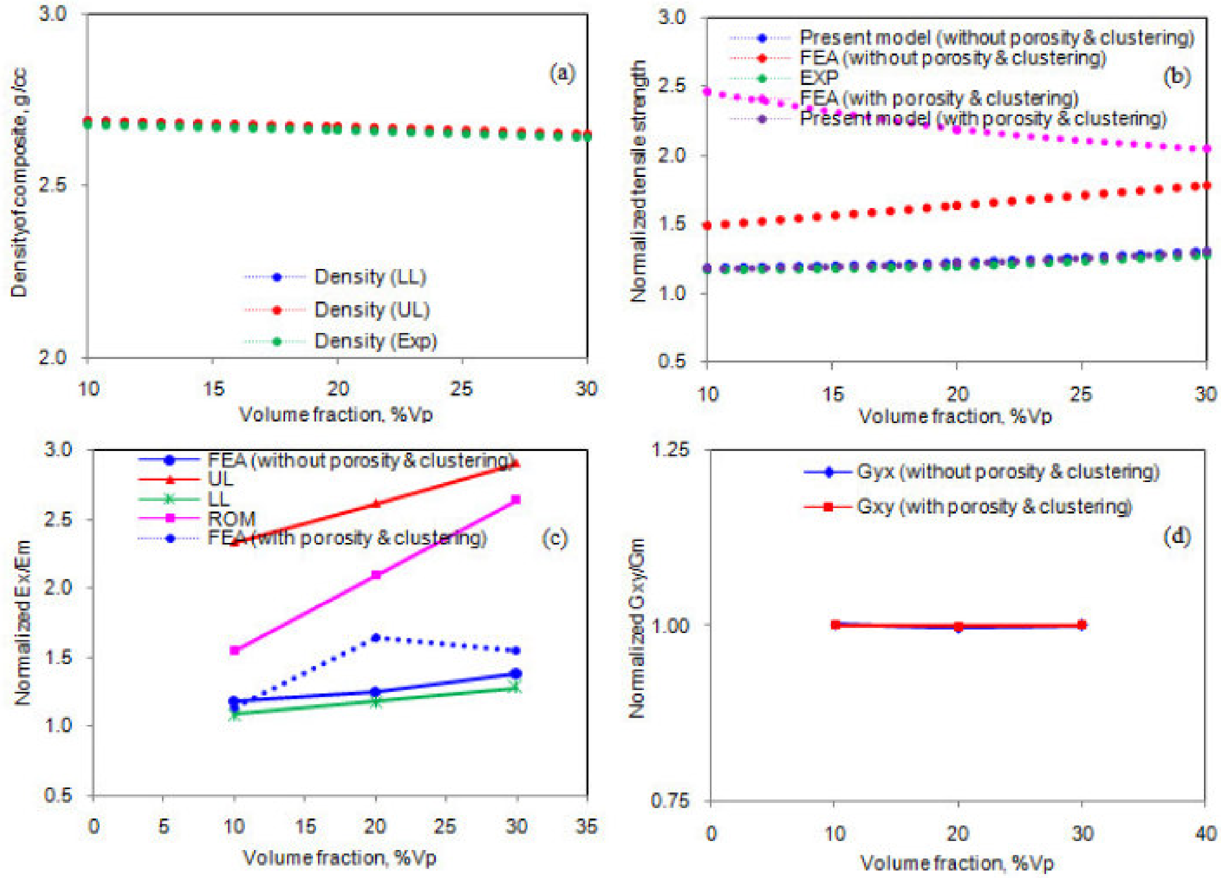

Figure 3: Effect of volume fraction on (a) density (b) normalized tensile stress, (c) normalized tensile elastic modulus and (d) normalized shear modulus of AA1100/B_4C composites.

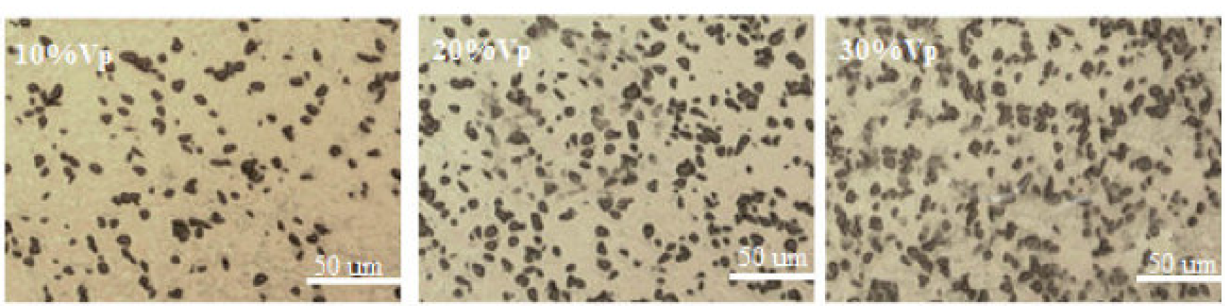

Figure 4: Microstructure showing distribution of B_4C nanoparticles, clustering and porosity in AA1100 alloy matrix.

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