Advances on Experimental and Numerical Modeling of Al-based Alloys and Nanocomposites Fabricated via Ultrasonic and Electromagnetic Processing

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Abstract

The metal-matrix-nano-composites (MMNCs) in this study consist of an Al alloy matrix (6061) reinforced with 1.0 wt.% SiC 50 nm diameter nanoparticles that are dispersed within the molten alloy matrix using ultrasonic cavitation (UST) and induction melting technologies. The required ultrasonic parameters to achieve the required cavitation for adequate degassing and refining of the Al alloy as well as the fluid flow characteristics for uniform dispersion of the nanoparticles into the 6061 alloy matrix are being investigated in this study by using an in-house developed magneto-hydro-dynamics (MHD) model.

The MHD model accounts for turbulent fluid flow, heat transfer and solidification, electromagnetic field as well as the complex interactions between the solidifying alloy and nanoparticles by using ANSYS Maxwell and ANSYS Fluent Dense Discrete Phase Model (DDPM) and a particle engulfment and pushing (PEP) model. The PEP model accounts for the Brownian motion. The MHD model is coupled with a stochastic microstructure model to predict the formation of the microstructure during the UST and electromagnetic stirring (EM) processing of alloys and nanocomposites.

Scanning electron microscope (SEM) analysis was performed on the as-cast MMNC coupons processed via ultrasonic cavitation dispersion technique (UCDS) and confirmed the distribution of the nanoparticles predicted by current model. A parametric study was performed using the validated model. The study includes the effects of electromagnetic field from the induction coils and the magnitude of the fluid flow.

The effects of UST on the solidifying microstructure of the A356-based alloys and nanocomposites was also studied experimentally and numerically. Fine globular grain structures (of about 10-20 microns) were observed in the cast samples obtained via UST during solidification. Also, the eutectic microstructure was greatly modified when UST was applied during solidification. The predicted microstructures by the stochastic microstructure model are very similar with the measured ones in terms of their dimensions and morphologies. Thus, the MHD model coupled with the stochastic microstructure model can successfully be applied to assist in scaling up and optimization of the UST and EM processing of alloys and nanocomposites.