Abstract

The thesis presents a novel *two-step ultrasonic casting* technique for development of bulk metal matrix nanocomposites with a view of producing high strength-to-weight ratio materials and green light-weight materials. A newer feeding technique called *layer-wise feeding* is used in the two-step ultrasonic casting for enhancing the efficacy of the particle dispersion in the liquid melt during contact ultrasonication. The main focus is on studies of effects of two-step ultrasonication on the dispersion of hard ceramic nano-sized dispersoids in the ductile matrices using ultrasonic casting technology.

Using the newer two-step technique, an unprecedented uniform distribution of $Al_2O_3$ nano-dispersoids was achieved in the Al matrix. For comparison, the Al-$Al_2O_3$ nanocomposites were also produced by conventional contact and non-contact processes. All the nanocomposites were characterized using Scanning Electron Microscope (SEM), X-Ray Diffraction (XRD), Energy-dispersive X-ray spectroscopy (EDS), Transmission Electron Microscope (TEM), and Electron Back Scattered Diffraction (EBSD) techniques. Mechanical property testing viz., Vickers microhardness and tensile tests were carried out.

The microstructure studies revealed that, in the absence of sonication during solidification i.e, contact ultrasonic casting, zones of lower cooling rates were formed due to release of latent heat from adjacent grains. Those zones resulted in pushing and also grains with devoid of nano-particles. Such non-uniformity in cooling rates between the grains was eliminated by the ultrasonication during solidification, and eventually, grains with homogeneous particle distribution were formed as a result of two-step ultrasonication. The elimination was attributed to the powerful micro-convection due to ultrasonication during solidification. A comparative study on distribution of particles as result of the three types of the ultrasonic casting processes is presented in this work.

Further, the technique was extended to two-phase alloys to disperse $Al_2O_3$ nano-particles in a Al-3wt.%Cu alloy and also in the most widely preferred marine grade AA5083 alloy. However, in these nanocomposites, the two-step technique was not able to completely eliminate the zones of lower cooling rates, yet no clustering was observed in the microstructures. Such variation in microstructures as a result of composition variation was explained on the basis variation of wettability of $Al_2O_3$ in Al due to solute addition.

In all the three types of nanocomposites, the two-step process resulted in— (a) enhanced particle distribution both in the liquid melt and in the casting, (b) grain refinement, and (c) excellent mechanical properties. An attempt was made to explain the improved mechanical properties on the basis of known strengthening mechanisms.

**Keywords**: Cavitation, Agglomeration, Deagglomeration, Ultrasonication, MMNC, Nanocomposite, Microstructure, Wettability, Ultrasonic casting, Pushing, Climb mechanism, Al-$Al_2O_3$, Al-3Cu-$Al_2O_3$, AA5083-$Al_2O_3$