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Influence of pressure field in melts on microstructure formation in solidification processing

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ABSTRACT

It is well known that external fields applied to melts can cause nucleation at lower supercooling, fragmentation of growing dendrites, and force convection around solidification front. All these effects contribute to the development of finer microstructure. In this paper, we analyze how pressure field created with ultrasonic vibrations influences structure refinement in terms of supercooling and dendrite fragmentation. Pressure field was estimated with simplified analytic solution as well as using commercial finite element software. Decreased pressure leads to cooling of the melt, but this cooling is not significant to be an important factor. It is localized increase in pressure that can lead to significant supercooling when the increase in solidus temperature overcomes heating by compression. Cavitation creates largest pressure variations, resulting in the most efficient grain refinement. Simulation and experiments with water samples show that pressure filed favorable for cavitation is restricted to relatively narrow zone around the acoustic source immersed in the liquid. High pressure around collapsing bubbles both nucleates solid phase and ejects it in the liquid. As a result, fine grains are seeded throughout the liquid leading to the solid with finer grains. Fragmentation of dendrites due to mechanical action of bubbles is efficient only if bubbles collapse during interaction with growing dendrites. Remelting of dendrites due to acoustic streaming does not seem to be a major factor in the grain refining.

KEYWORDS: ultrasound, cavitation, solidification, nucleation, grain refinement