Role of dendritic equiaxed grains in macrosegregation formation: numerical modeling of laboratory benchmark and solidificaion of industrial ingot

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Abstract: This thesis concerns the solidification of alloys and more particularly the modeling of macrosegregation in metallurgical ingots due to the growth of equiaxed grains in motion within the liquid phase. The development of a numerical model based on volume average method is presented, followed by tests on benchmark experiments and by an application to the casting of an industrial ingot. First, a modernized three-phase multiscale equiaxed solidification model has been developed, in which a new expression of the diffusion length required in the equation of grain growth has been introduced. The drastic effect of the diffusion length model has been demonstrated through simulations for solidification of Sn-5 wt% Pb alloy in a brick-shaped cavity that mimics the Hebditch-Hunt experiment. Then, the reliability of that new equiaxed solidification model has been tested using a numerical simulation of the AFRODITE benchmark experiment on solidification of Sn-10 wt% Pb alloy with electromagnetic stirring. The predicted distributions of temperature during the solidification and of the final macro-segregation agreed well with experimental results. The effect the intensity of the Lorentz force used for stirring on final macrosegregation pattern has been analyzed numerically. Finally, the equiaxed solidification model developed in this work has been used to study the formation of macrosegregation in a 2.45 ton industrial steel ingot. The formation mechanism of macrosegregation in the ingot has been analyzed and the effect of cooling intensity has been studied. In addition, the effect of electromagnetic stirring on solidification process and macrosegregation formation in the ingot has been investigated through a series of simulations.