Coupling Simulations of Growth and Motion of Dendrite by Phase-field Lattice Boltzmann Method

T. Takaki*, R. Rojas† and M. Ohno††

* Mechanical and System Engineering, Kyoto Institute of Technology
Matsugasaki, Sakyo, Kyoto 606-8585, Japan
e-mail: takaki@kit.ac.jp, web page: http://www.cis.kit.ac.jp/˜takaki/

† Mechanical and System Engineering, Kyoto Institute of Technology
Matsugasaki, Sakyo, Kyoto 606-8585, Japan
e-mail: rojas@kit.ac.jp

†† Faculty of Engineering, Hokkaido University
Kita 13 Nishi 8, Kita, Sapporo, 060-8628 Hokkaido, Japan
e-mail: mohno@eng.hokudai.ac.jp

ABSTRACT

Typical solidification microstructures consist of equiaxed and columnar structures. During solidification, convection of liquid plays a crucial role on both solidification structures. Here, the growth direction of columnar structures is changed by the convection [1], and free dendrites flowing within the melt form the equiaxed structures [2].

Due to some computational advantages over other numerical techniques, the phase-field method (PFM) has emerged as the most powerful numerical tool to simulate dendritic solidification [3]. The PFM has been also applied to dendritic growth in fluid flow [4]. However, almost all simulations have been carried out for fixed dendrites in fluid flow, and only few phase-field studies have been done for moving dendrites [5]. Recently, we have developed a phase-field lattice Boltzmann method (PFLBM) which can simultaneously simulate dendritic growth, and translation and rotation of the solid phase in fluid flow [6].

In this study, by using the PFLBM, we simulate dendritic growth with motion induced by fluid flow at various conditions, such as in forced flow, rising and sinking due to gravity, multiple dendrites, and so on. To accelerate those simulations, we perform parallel computing using multiple graphics processing units (GPUs) [7].

REFERENCES

[1] K. Murakami, T. Fujiyama, A. Koike and T. Okamoto, “Influence of melt flow on the growth directions of columnar grains and columnar dendrites”, *Acta Metall.*, **31**, pp. 1425-1432, (1983).

[2] H. Yasuda, Y. Yamamoto, N. Nakatsuka, M. Yoshiya, T. Nagira, A. Sugiyama, I. Ohnaka, K. Uesugi and K. Umetani, “In situ observation of solidification phenomena in Al-Cu and Fe-Si-Al alloys”, *Int. J. Cast Met. Res.*, **22**, pp.15-21, (2009).

[3] T. Takaki, “Phase-field Modeling and Simulations of Dendrite Growth”, *ISIJ Int.*, **54**, 437-444, (2014).

[4] C. Beckermann, H.J. Diepers, I. Steinbach, A. Karma and X. Tong, “Modeling Melt Convection in Phase-Field Simulations of Solidification”, J. Comput. Phys., **154**, 468-496, (1999).

[5] M. Do-Quang, G. Amberg, “Simulation of free dendritic crystal growth in a gravity environment”, J. Comput. Phys., **227**, 1772-1789, (2008).

[6] R. Rojas, T. Takaki and M. Ohno, *submitting*.

[7] T. Takaki, T. Shimokawabe, M. Ohno, A. Yamanaka and T. Aoki, “Unexpected selection of growing dendrites by very-large-scale phase-field simulation”, J. Cryst. Growth, **382**, 21-25, (2013).