Strategic Young Researcher Overseas Visits Program

for Accelerating Brain Circulation 2011

"Development of Young Researchers Based on International Joint Research on Green Energy Systems" Progress Report

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2. Title: Associate Professor

3. Host Institution: University of Nottingham (England)

4. Host Researcher: Professor Yuying Yan

5. Duration: 18-August-2012 – 05-October-2013

6. Research Topic:
Study for the heat and mass transfer on biomimetic functional surfaces and phase changes in order to develop next-generation technologies on the green energy

7. Overview of the Results of the Collaborative Research:

Development of athermal Lattice Boltzmann method for two-phase flow with large density difference in complex boundary structure

The heat pipe is one of the interesting thermal devices nowadays. If we want to improve the performance of the heat pipe, the wick structure and knowledge of vapour-liquid two-phase flow in the wick are important, because these significantly affect the performance of the heat pipe. Since the wick structure and the two-phase flow in the wick are very complex, we want to simulate two-phase flow in the wick

numerically.

In order to simulate two-phase flow in the sintered wick of heat pipes, we compute the mass transfer of two-phase flow having large density difference in the complex boundary by a lattice Boltzmann method (LBM) proposed by Inamuro et al in 2004 and Yan et al in 2010. We introduced following two points to this simulation method. One of our aims is to simulate the two-phase flow in a sintered wick. So we want to adapt the numerical method to the complex boundary. We added an extra layer to the boundary and calculated the values on these lattices by extrapolation method. Moreover, the interpolation function of the viscosity coefficient was modified to satisfy the continuity of the viscosity flux across the phase interface. Since the values of viscosity are quite different between the liquid and the gas phase, the viscosity in the transition region affects the results. Figures 1 and 2 show the aggregation behaviour of large density phase from random density distribution, and the behaviour of bubbles between spheres arranged in a face centred cubic lattice, respectively. We have succeeded in simulating two-phase flow having large density difference by LBM. We are going to implement a thermal model and control of the wettability as our future work.

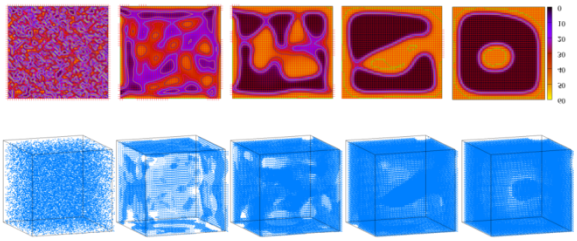

Fig. 1 Result of simulation: aggregation behaviour of large density phase from random density distribution

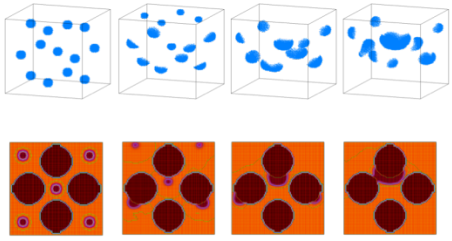

Fig. 2 Result of simulation: behaviour of bubbles between spheres arranged in face centred cubic lattice

MRI measurement of water transport in plant stem

Prof Yan's group and I are trying to measure the water transport in the plant stem by means of MRI in order to improve the water transport and structure of the wick in the heat pipe. The tall trees can deliver the water up to more than tens of metre height. We intend to get the hints to improve the performance of thermal devices from nature. Figure 3 shows a sample small plant, named 'Salix Flamingo', in which we had measured water distribution as a pilot study. Figure 4 shows a result of measurement visualised by MATLAB. We can see that the water is circumferentially deflected in the stem.

Fig. 3 Picture of the 3-tesla MRI and a plant

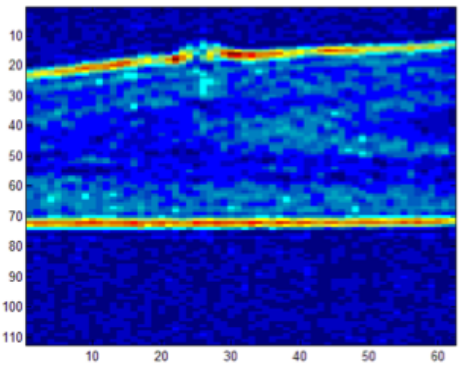

Fig.4 Water concentration profile in a plant stem

8. Deployment Plans for Future Collaborative Research:

Prof Yan and I have an agreement to continue our collaboration on the research of the lattice Boltzmann method for two-phase flow with the large density difference. We intend to extend our simulation program of LBM to the thermal model.

Since we want to continue the MRI measurement of the water delivery in plant's stem in order to improve the performance of heat pipe, we are going to advance our research at each institute. Prof Yan can use MRI facilities at MR center in the University of Nottingham and I will be able to use MRI facilities at Nagasaki University Hospital. Moreover, we are applying for some research funds.

9. List of Collaborative Research Progress:

Publication(s)

1) Yamaguchi, T., Wan, Q., Yan, Y.Y. and Hong, J., Numerical simulation of liquid-gas two-phase flow with large density difference in multi-layered sintered wick by the lattice Boltzmann method, Proceedings of 15th International Heat Transfer Conference, Kyoto, Japan, 2014.8, (under review)
2) Yamaguchi, T., Wan, Q. and Yan, Y.Y., Numerical analysis of two-phase flow in sintered copper wick by lattice Boltzmann method, Proceedings of the ASME 2013 11th International Conference on Nanochannels, Microchannels, and Minichannels

(CD-ROM), Sapporo, Japan, 2013.6, ICNMM2013-73205

Conference Presentations

1) Yamaguchi, T., Wan, Q., Yan, Y.Y. and Hong, J., Numerical simulation of liquid-gas two-phase flow with large density difference in multi-layered sintered wick by the lattice Boltzmann method, 15th International Heat Transfer Conference, Kyoto, Japan, 2014.8, (under review)
2) Yamaguchi, T., Lattice Boltzmann simulation of liquid-gas two-phase flow with large density difference in complex boundary, Keynote speech in the International Heat Transfer Symposium 2014 (IHTS2014), 2014.5, Beijing, China, IHTS14K004
3) Yamaguchi, T. and Yan, Y.Y., Numerical simulation of liquid-gas two-phase flow in sintered wick with face-centred structure by the athermal Lattice Boltzmann Method, 9th UK–Japan Seminar on Multi-Phase Flows 2013, London, UK, 2013.9
4) Yamaguchi, T., Wan, Q. and Yan, Y.Y., Numerical simulation of liquid-gas two phase-flow in sintered wick with face-centred structure by the athermal Lattice Boltzmann Method, 13th UK Heat Transfer Confernece 2013, London, UK, 2013.9, UKHTC2013-185
5) Yamaguchi, T., Wan, Q. and Yan, Y.Y., Numerical analysis of two-phase flow in sintered copper wick by lattice Boltzmann method, The ASME 2013 11th International Conference on Nanochannels, Microchannels, and Minichannels, Sapporo, Japan, 2013.6, ICNMM2013-73205
6) Yamaguchi, T., Numerical Analysis of Bubbles Flow in 3D Sintered Wick by Lattice Boltzmann Method, Invited presentation at International workshop on “Numerical heat and mass transfer from a view point of multiscale analysis”, Nottingham, UK, 2013.5