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The fluid flow and heat transfer problems encountered in industry applications span into different scales and there are different numerical methods for different scales problems. Multiscale methods are needed to solve problems involving multiple scales. In this dissertation, multiscale methods are developed by combining various single scale numerical methods, including lattice Boltzmann method (LBM), finite volume method (FVM) and Monte Carlo method. Two strategies exist in combing these numerical methods. For the first one, the whole domain is divided into multiple subdomains and different domains use various numerical methods. Message passing among subdomains decides the accuracy of this type of multiscale numerical method. For the second one, various parameters are solved with different numerical methods. These two types of multiscale methods are both discussed in this dissertation.

In Chapters 3 and 4, the whole domain is divided into two subdomains and they are solved with LBM and FVM respectively. This LBM-FVM hybrid method is verified with lid driven flows and natural convections. In Chapter 5, a LBM-FVM hybrid method is proposed to take both advantages of LBM and FVM: velocity field and temperature file are solved with LBM and FVM respectively. MCM has advantages in solving radiative heat transfer, and LBM-MCM hybrid method is proposed in Chapter 6.

Numerical investigation for melting problems are carried on in this dissertation. The key point in solving the melting problem is how to obtain the interface location. To overcome the disadvantages in the now existing numerical methods, an interfacial tracking method is advanced to calculate the interface location. In Chapter 7, low Prandtl fluid natural convections are solved with LBM to discuss the oscillation results. Based on these results, low Prandtl number melting problems are solved using LBM with interfacial tracking method in Chapter 8. High Prandtl number melting problems in a discrete heated enclosure are solved using FVM with interfacial tracking method in Chapter 9. To take both advantages of LBM and FVM, melting problems are solved with LBM-FVM hybrid method in chapter 10, while interfacial tracking method is advanced by porous media assumptions in fluid flow field simulation process.

Problems in Chapters 3-10 are all in two-dimensional and three-dimensional problems are more general than them in the realistic applications. Double LBM-MRT model for three-dimensional fluid flow and heat transfer is proposed and three types of natural convections in a cubic cavity are discussed in Chapter 11. For the first two types of cubic natural convections, the present results agreed very well with the benchmark solutions or experimental results in the literature. The results from the third type exhibited more general three-dimensional characters. Three-dimensional melting problems are solved with the proposed double LBM-MRT model with interfacial tracking method in Chapter 12. Numerical results in three conduction melting problems agree with the analytical results well. Taking Chapter 11 results in consideration, the double LBM-MRT model with interfacial tracking method is valid to solve three-dimensional conduction or convection controlled melting problems. Two convection melting problems in a cubic cavity are also solved. With a lower Rayleigh number, the convection effects are weaker; side wall effects are smaller; melting process carries on slower.