§3. Gyrokinetic Particle Simulation of Kinetic Internal Kink Modes

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Parallel computing is promising the scalable high speed execution of simulation codes with the number of processors. By the use of parallel computer, unimaginable progress in the plasma simulation can be expected. The three dimensional magneto-inductive gyrokinetic particle code GYR3D [1,2,3] is ported to a massively parallel computer, Intel Paragon XP/S15-256, which has 256 scalar processors (nodes) connected with a two-dimensional mesh topology. The Fortran77 compiler with message-passing subroutines (NX communication library) is used. The standard techniques of parallelization are used such as domain decomposition and data transpose. No special technique was used for the load balance because we used the same size sub-domains and an almost equal number of particles per sub-domain since the density profile is uniform in space. Even in the non-uniform case, it may be possible that we do not need the load balance technique because, in the δf code, we can select the distribution of markers uniformly in space. We only decomposed the domain in the z direction. The best results were obtained when the number of meshes in z, N_z, is equal to the number of decomposition ,N_{divz}. In our case, N_z is usually smaller than the number of nodes, N_{node}. Therefore we used N_{node}/N_{divz} replicas. It is found that the speed of the parallelized code scales well with the number of nodes. The speed of the parallelized GYR3D with 256 nodes is more than three times faster than that of the vectorized GYR3D on NEC SX-3/24R (vector/parallel computer) with one node. This speed ratio is consistent with the ratio of peak speeds of these computers.

The parallelized GYR3D code was applied to the simulation of the $m = 1$ (poloidal) and $n = 1$ (toroidal) kinetic internal kink mode in tokamaks. A convergence study was done in the limit of extremely large number of particles. The results show the very good energy conservation when about eight million particles are used. It is important to note that the number of particles did not influence the linear phase of the instability. Also the number of particles had only a slight influence on the nonlinear phase in the very long runs. This is explained in the following. Usually the error in energy conservation reflects the error in the total kinetic energy of electrons which comes from the contribution of the high energy electrons. The error in the kinetic energy did not significantly influence the temporal evolution of collective modes. This is because field quantities are determind by the lower order moments such as charge and current densities. The other finding in this paper is the existence of the quadrupole potential profile around the reconnection point in the secondary phase after the full reconnection. This clear mode structure is obtained by including higher n modes by reducing the time step size.

It is found that three-dimensional gyrokinetic particle codes with a δf method are very powerful tools in simulating the kinetic modification of MHD modes. However, more powerful parallel computers with greater than 1 tera flops are required for simulation with parameters of existing and next generation tokamaks. The particle simulations for such tokamaks need intensive research on the architecture of parallel computers and on the parallel computing algorithms.

References

1) Naitou, H., Journal of Plasma and Fusion Research 70 (1994) 135.
2) Naitou, H., Tsuda, K., Lee, W.W., Sydora, R.D., Phys. Plasmas 2 (1995) 4257.
3) Naitou, H., Sonoda, T., Tokuda, S., Decyk, V.K., Jouunal of Plasma and Fusion Research 72 (1996) 259.