§3. Development of Moving Boundary MHD Code Based on the Vector Potential

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Many MHD codes, in which the full-MHD equations are numerically solved, have been developed[1,2]. These codes have been used to investigate the MHD phenomenon in the LHD. In these codes, however, the solenoidal condition for the magnetic field is not guaranteed. In addition, the deformation of plasma due to the MHD instabilities cannot be precisely calculated since the plasma-vacuum boundary is virtually fixed at the last closed flux surface (LCFS) of the equilibrium plasma. We aim to develop a new MHD code to clear these problems and to apply it to the LHD plasmas. It is also our purpose of this study to investigate the effects of the broken solenoidal condition and/or the plasma deformation to the MHD simulations.

We adopt the real coordinate system and the pseudo-vacuum model to appropriately treat the plasma deformation due to the MHD instability. In the pseudo-vacuum model, the vacuum region between the plasma and the vessel wall is supposed to be filled with the high resistivity and low pressure plasma. The resistivity in the pseudo-vacuum region is assumed to change in time, depending on the plasma pressure. The time evolution of the vector potential instead of the perturbed magnetic field is numerically solved in the developed code to satisfy the solenoidal condition.

As the computational techniques, the 4th order finite difference method, the 4th order Runge-Kutta method and the Rational Constrained Interpolation Profile (R-CIP) method[3] are used. To prevent the numerical oscillation, MmB method[4] is also adopted.

We developed the linear and non-linear MHD codes based on the above models. The developed codes are applied to the simple cylinder plasma equilibrium (Fig. 1) and the validities of our codes are checked. The initial velocity $\boldsymbol{V} = \boldsymbol{V}(r)\sin(\theta + Z)$ is given and time evolution of $\rho, \boldsymbol{V}, P$ and $\boldsymbol{A}$ is calculated.

Time evolution of energy and the kinetic energy profile on $Z = \pi/5$ surface at $t = 50$ are shown in Figs. 2 and 3, respectively. It can be seen from these figures that the perturbation linearly grows after $t \simeq 30$ and that the plasma shape changes due to the growth of instability. The growth rate is estimated from Fig. 2 as $\gamma = 0.76$. This value is 20% larger than the theoretical growth rate of kink mode. The large perturbation can be seen on the boundary between the plasma and the pseudo-vacuum region. This is due to the finite difference error on the plasma boundary across which the physical quantities, such as the magnetic field, are indifferentiable.

We will modify the code to appropriately treat the indifferentiable quantities between the plasma and pseudo-vacuum regions and apply the LHD plasma.

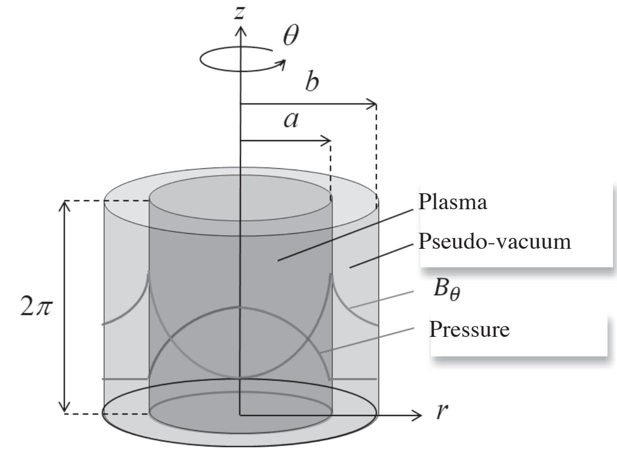

Fig. 1. Assumed cylinder plasma equilibrium. Pressure is given as $P = P_0(1-(r/a)^4)$.

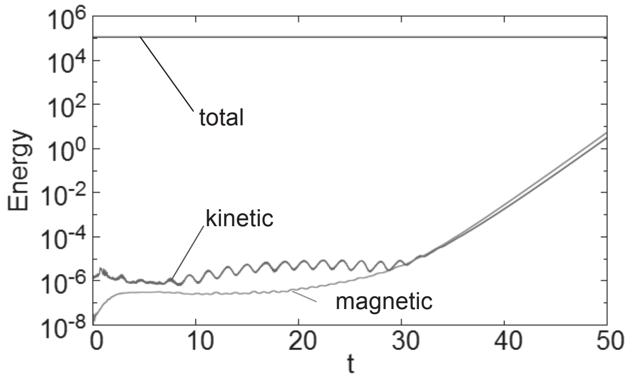

Fig. 2. Time evolution of total, kinetic and magnetic energy.

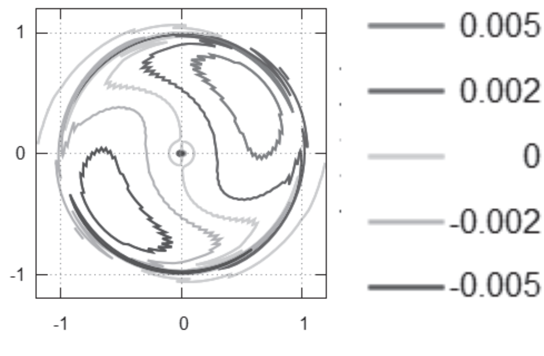

Fig. 3. Kinetic energy profile on $Z = \pi/5$surface at $t = 50$.

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3) Xiao, F. *et al.*: Comput. Phys. Commun. **94** (1996) 103.
4) Huamo, W., Shuli, Y.: IMPACT Comput. Sci. Eng. **1** (1989) 217.