§16. Development of Nonlinear MHD Code

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In the recent LHD experiments, high performance discharges have been successfully carried out in the configuration with inward shift of the magnetic axis, and the average beta value of 3% was achieved. Previously, the linear MHD stability code, RESORM, was developed based on the reduced MHD equations for stellarator configurations[1]. The linear stability study with smooth pressure profiles showed that the low-n ideal interchange modes become unstable at lower beta than the experimentally obtained value. In order to resolve the difference between the experiments and the theory, stabilizing mechanism for the interchange mode must be taken into account. As one of the mechanisms, local flattening of the pressure profile around the resonant surface was proposed. The linear analysis showed that step-like profile of the pressure can effectively stabilize the multiple modes with different n simultaneously[2].

In order to study whether such profile can be generated spontaneously as a result of the self-organization of the plasma, the nonlinear MHD code is developed by extending the RESORM code. This makes us understand easily the relation between the linear and the nonlinear results. The flux coordinates are employed to simplify the magnetic differential operator. The dependence of the poloidal and the toroidal angles are expressed by the Fourier series, and the mode coupling is calculated through the convolution of the Fourier coefficients. The multi-helicity components of the perturbations can be treated. For the time evolution, the two-step explicit algorithm is employed, while only the Laplacian operators are treated implicitly in each step. This code examines three-dimensional (3D) equilibrium which is calculated by using the VMEC code. The inputs for the code are obtained by averaging the 3D quantities in the toroidal direction following the stellarator expansion method. Therefore, the toroidal effects are included automatically.

A preliminary result has obtained with the nonlinear code for an LHD equilibrium with $R_{ax} = 3.75m$ at $\beta_0 = 4\%$. Figure 1 shows the equilibrium pressure profile given by $P = P_0(1-\rho^4)^2$. The surfaces with $\iota = 1/2$ and $2/3$ are in the Mercier unstable region. Following the time evolution, we obtained nonlinear saturation. Figure 2 shows the saturated pressure profile. The local flattening is seen around the $\iota = 1/2$ and $2/3$ surfaces. This result may suggest the the self-organization occurs so as to stabilize the unstable modes.

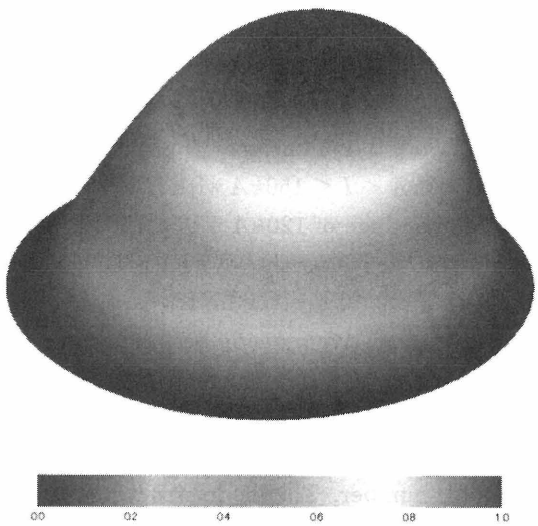

Fig.1 Equilibrium pressure profile.

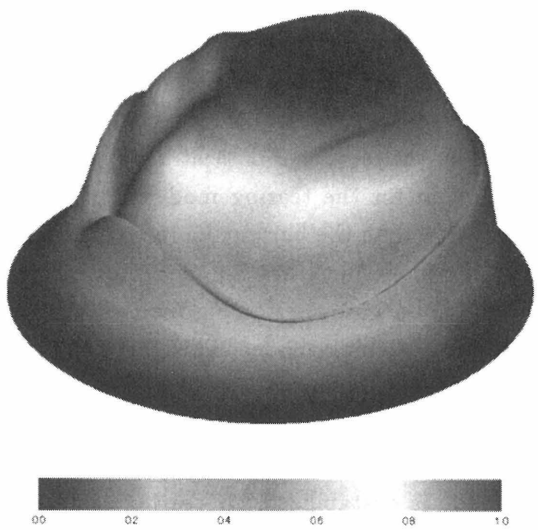

Fig.2 Saturated pressure profile.

References

1) Ichiguchi, K., et al., Nucl.Fusion **29**,(1989)2093.
2) Ichiguchi, K., et al., Nucl.Fusion **41**,(2001)181.