5 ZHOU Yan, DENG Zhongchao, DIAO Guangyue, et al. Density Sawteeth during LHCD in the HL-1M Tokamak. Nuclear Fusion and Plasma Physics (in Chinese), 1999, 19(1): 55

6 Okazaki T, Sugihara M, Fujisawa N. Lower Hybrid Current Drive in the Presence of a DC Electric Field. Nuclear Fusion, 1986, 26(8): 1029

3.9 The Four-fluid Model and Toroidal Momentum Transport

QU Hongpeng GAO Qingdi

Key words Four-fluid model Toroidal momentum transport

In order to explain some recent experiment results and find new ways to improve the plasma performance, the study of the toroidal momentum transport and the space structure of radial electric field have drawn more and more attention in tokamak plasma research.

To date, the theoretical analysis of plasma toroidal momentum transport is mainly based on the general MHD model. However, the ordinary MHD model fails to deal with the constraint conditions on the motions of the trapped particles and the corresponding forces. Therefore, from this model, it is impossible to derive the correct relations of flows and acting forces for the banana collision region in tokamak plasmas. Thus, the ordinary MHD model is not a justified start point to investigate the momentum transport and spatial structure of the radial electric field.

Owning to allowing for the constraint conditions on the motions of the trapped particles, the so-called four-fluid model remedies the substantial defect of the ordinary MHD model[1]. The strong point of the four-fluid model is that not only it is a true fluid model but also we can easily obtain various neoclassical particle flows based upon it. Mechanically, the four-fluid model provides a more solid foundation for the research of toroidal momentum transport and the radial electric field. In this paper, the four-fluid model is extended to accommodate the case with the viscosity force and toroidal momentum injection, and the following toroidal momentum transport equation is derived:

$$-m_i \frac{\partial v_{iu,\parallel}}{\partial t} + m_i \chi_\parallel \frac{\partial^2 v_{iu,\parallel}}{\partial r^2} + f_{iu}^{NBI} - k_2\left(v_{iu,\parallel} + \frac{c}{B}\frac{1}{en}\frac{dp_i}{dr}\right) = 0 \quad (1)$$

In Eq. (1), $k_2 = \frac{1}{k_1}\frac{\sigma_r}{n_{iu}}\frac{B_\theta^2}{c^2}$ and $k_1 = 1 + \frac{B_\theta^2}{c^2}\frac{n}{n_{it}}\frac{\tau_{ii}}{m_i}\frac{\sigma_r}{n_{iu}}$, $v_\parallel$ and p_i are the toroial velocity and ion pressure respectively, m_i is the mass of ion, $\chi_\parallel$ is the toroidal momentum diffusivity, f_i^{NBI} is the tangential force from neutral beam injection. The toroidal momentum transport and radial electric field are coupled in the four-fluid model. In this paper, for simplicity, a formal radial ohm law is assumed to determine the radial electric field, and the specific mechanism to form the ambipolar electric field is dodged on purpose.

From above results, we can easily find that the profile of toroidal velocity and radial electric field can be adjusted by controlling tangential injection of neutral beam. As we know, this is very important in the research of the improvement of plasma confinement. Furthermore, because the distribution of radial field is related to the toroidal momentum diffusivity, maybe it could offer a new way to explain the formation and sustentation of transport barrier.

REFERENCE

1 QU Hongpeng, GAO Qingdi, SHI Bingren. Equation for Quadruple Fluids and Perturbed Particle Flows in a Tokamak Plasma. Nuclear Fusion and Plasma Physics(in Chinese), 1998, 18(2): 11

3.10 The Extraction and Acceleration System of 60 kV, 70 A, 2 s Ion Source

WANG Huisan   JIAN Guangde

Key words Extraction and acceleration system of ion source   Ion beam optics characteristic

The 60 kV, 70 A ion source adopts 4 electrodes extraction and acceleration system that consists of plasma grid, gradient grid, acceleration grid and ground grid. Such a system usually is used in a higher energy ion source, the ions are extracted at lower energy and are post-accelerated to higher energy. Advantages of such a system are that it can extract higher ion beam density and can obtain better beam optics characteristic by means of adjusting the electric field strength ratio between extraction gap and acceleration gap.

The large area multislit extraction system is used to obtain high current beam. The area of each electrode grid is 45 cm × 16 cm, each and all consist of three modules. The area of each module is 15 cm × 16 cm. There are 18 slits at each module. Thus, the sum total of the slit is 18 × 3 = 54 slits at each electrode grid. The extraction slit size of the plasma grid is 0.35 cm × 16 cm, its transparency is about 42%.

To change the large beam cross section into 30 cm × 22 cm at 4.5 m away from the source, "focusing" is accomplished by inclining the outer two modules[1] (0.96° for 4.5 m focus). The beamlet optics characteristic extracted from the grid slit is still very important in spite of like that. For a slit type of ion extraction system, the ion beam divergence in direction parallel to the slit is ef-