§11. The Bootstrap Current Coefficient Calculations with the VENUS+δf Code in the Typical LHD Collisional Regime

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The LHD typical discharges have the electron temperature on the axis T_{e0} =1~2 keV and the electron density n_{e0}=1-3x10^{19} m^{-3}. These parameters correspond to the normalized collision frequency $\nu^* \leq 1$, the β values lay in the range 0.33-0.41%. Additional experimental setup description and the details were given in [1]. Fig. 1 shows the dependence of the total bootstrap (non-inductive) current obtained experimentally on the LHD magnetic configurations with the different magnetic axes.

Circles denote the experimental data and a line denotes the theoretical predictions of the bootstrap current by the SPBSC code in the Shaing-Callen limit ($\nu^* << 1$). The maximal positive bootstrap current 25 kA was experimentally obtained for the configuration with the magnetic axis R_{ax}=3.90m. Outward shift of the magnetic axis leads to the decreasing of the toroidal current. In according to the SPBSC predictions, the configuration with the R_{ax}=4.05m can have the negative bootstrap current –5 kA, the experimental measurements give –2~+2 kA (depending on the different temperature and density values).

In order to approach to the LHD experimental results in this paper, we calculate for the same LHD configurations with the VENUS+δf code the dimensionless bootstrap current coefficient D_{31}* [2].

To calculate the dependence of the LHD bootstrap current coefficients $D_{31}^*(R_{ax})$ with the VENUS+δf code, we take several LHD plasma boundaries spectra with the different magnetic axes, obtained inside the real LHD coils. Solving the drift equations for each particle together with the linear Fokker-Planck equation for the particle weight along the VENUS numerical trajectory, after several collision times we get the steady state solution for the bootstrap current coefficient.

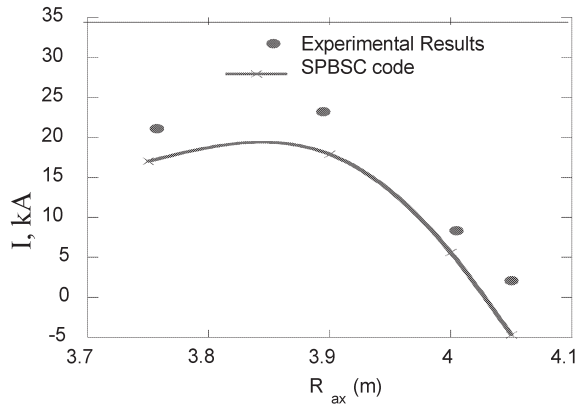

Fig. 1. The magnetic axis position dependence of the experimental bootstrap current and the bootstrap current from the SPBSC predictions.

Typical LHD collisional regime with the effective normalized frequency $\nu^* \leq 1$ can be reproduced by the VENUS+δf code using the Lorentz pitch angle scattering with the inverse mean free path values ν/V=0.003-0.01 [1/m]. Bootstrap current coefficients D_{31}* as a function of normalized plasma radii *r/a=0.2, 0.5, 0.8* (*r/a=1* corresponds to the plasma boundary) for the different magnetic axes, calculated with the VENUS+δf code for the collisional regime with the uniform inverse mean free path ν/V=0.003 [1/m] are shown in Fig. 2.

The largest positive bootstrap current coefficient, equals to 0.4, is obtained for the LHD configuration with the magnetic axis R_{ax}=3.90m and ν/V=0.003 [1/m]. Outward shift of the magnetic axis decreases the value of D_{31}*, the configurations with the magnetic axes R_{ax}=4.05m and 4.10m have negative bootstrap current coefficient for all plasma radii. The bootstrap current coefficient for the configuration with the magnetic axis R_{ax}=3.95m is positive near the plasma edge and negative in the middle of plasma column.

Such tendency of the bootstrap current coefficient behavior corresponds to the LHD experimental results and to the SPBSC predictions (compare with Fig. 1). In Fig.2, we do not take into account that in real LHD experiments the collisional regime is not uniform with respect to the plasma radius.

Accurate calculation of the total bootstrap current with the VENUS+δf code using the $D_{31}^*(r/a, R_{ax}, \nu/V)$ database together with the experimental LHD temperature and density profiles, will be performed in near future.

[1] K.Y.Watanabe et al., J. Plasma Fus. Res. SER., **5,** 124(2002).
[2] M. Isaev et al., Fus. Science&Techn., **50**, 440(2006).

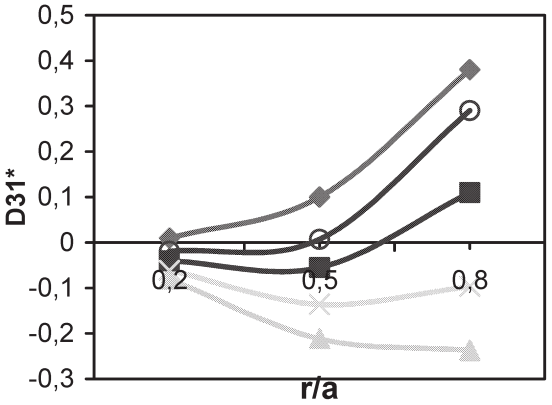

Fig.2. VENUS+δf bootstrap current coefficients D_{31}^* versus the normalized plasma radius *r/a* for the LHD configurations with the different magnetic axes R_{ax}=*3.90m* (rhombs), *3.95m* (circles), *4.00m* (quadrates), *4.05m* (crosses), *4.1 m* (triangles) for the collisional regime with ν/V=0.003 [1/m].