Comparison of measured and simulated parallel flows at the edge plasma of MAST

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Abstract

A comparison is presented of measured and simulated parallel flows in the low field side scrape-off layer of MAST Ohmic shots. Simulations with the B2SOLPS5.0 code reproduce the experimentally observed co-current rotation direction. The absolute values of the simulated Mach number are smaller than those of the measured ones; the difference is up to a factor of two. It is demonstrated that in both the simulations and the experiment the parallel velocity increases with temperature and decreases with poloidal magnetic field.

1. Introduction

Parallel velocity at the edge plasma has been measured using Mach probes for various tokamaks: JET [1], ASDEX Upgrade [2], Alcator C-MOD [3] and others. There were also several simulations of the parallel flows in the scrape-off layer (SOL) performed by the fluid codes EDGE2D [4], UEDGE [5], B2SOLPS5.0 [6]. The Mach numbers obtained in the simulations are usually smaller by a factor 1-3. In particular, a T/B_x parametric dependence (T is the SOL temperature, B_x is the SOL poloidal magnetic field) has been observed in the simulations [6]. It was also found that the density and toroidal magnetic field dependence is rather weak for these flows.

In the simulations reported in [6], the parametric scan was performed with other parameters being constant. In real Ohmic shots it is not true. The aim of this paper is to simulate real MAST Ohmic discharges with varying parameters corresponding to real discharges and to check the predicted T/B_x parametric dependence for the parallel SOL flows.

3. Simulation results

Five Ohmic shots with different temperatures and densities have been chosen for simulation. The measurements were made at the LFS equatorial mid-plane. The group of Mach probes measurements is shown in Fig.1. In order to study the temperature dependence of the parallel flow, two shots with almost the same density but different temperatures have simulated. The one example of second group of simulation results and measurements is shown in Fig.2. Here both density and temperature varied.

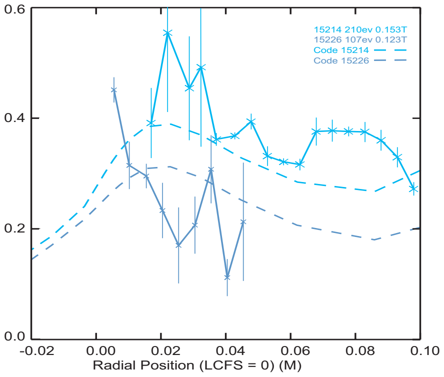

Fig.1. Mach number radial profiles of at the outer mid-plane (temperature scan).

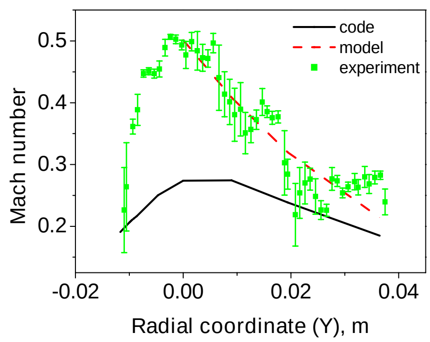

Fig.2. Mach number radial profiles at the outer mid-plane for scenarios №16290.

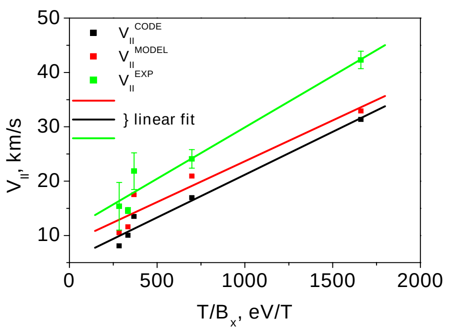

Fig.3. The absolute value of the parallel velocity at the reference point in the equatorial mid-plane 3 cm outside the separatrix as a function of the ratio of ion temperature to poloidal magnetic field for all scenarios.

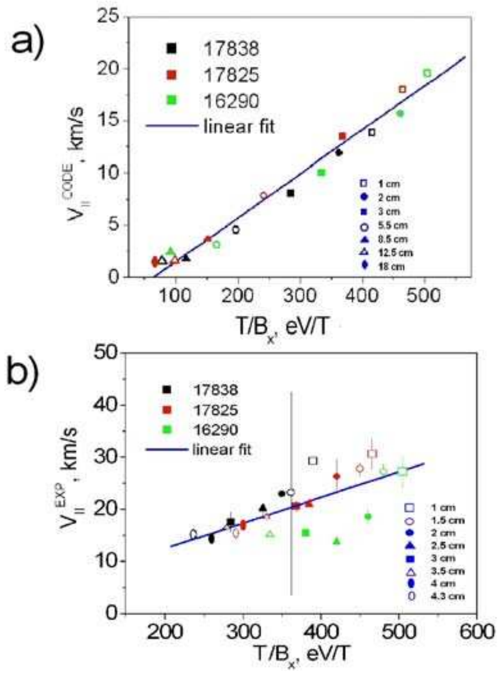

Fig.4. The absolute value of parallel velocity as a function of the ratio of ion temperature to poloidal magnetic field for scenarios №17838, №17825, №16290 taken at the equatorial mid-plane from distance 1cm to 5 cm outside the separatrix. a) simulation $V_{\parallel}^{CODE}$,the coefficient A in Eq. (5) is 0.027. b) experimental $V_{\parallel}^{EXP}$, the coefficient A in Eq. (5) is 0,05.

4. Discussion

Both simulations and measurements have the co-current parallel velocity in the SOL. The Mach number defined as

$$M = \frac{|V_{\|}|}{\sqrt{(T_e + T_i)/m_i)}} \quad (1)$$

is smaller in the simulations than the measured one, the difference is up to a factor of 2. This situation is also typical for other tokamaks [4]-[6].

In [6] it was demonstrated that the parametric dependence of the simulation results is consistent with the simple model expression

$$V_{\|}^{MODEL} = V_{\|}^{PS} + V_{\|}^{E}, \quad (2)$$

where

$$V_{\|}^{P.S.} = \left(\frac{1}{en_e h_y} \frac{\partial p_i}{\partial y} + \frac{1}{h_y} \frac{\partial \varphi}{\partial y} \right) \frac{B_z}{B_x B} \left(1 - \frac{B^2}{\langle B^2 \rangle} \right), \quad (3)$$

$$V_{\|}^{E} = \frac{1}{B_x} \frac{\partial \varphi}{h_y \partial y}. \quad (4)$$

Here $\partial / h_y \partial y$ is the radial (normal to the flux surface) derivative, B_x, B_z and B are poloidal, toroidal and total magnetic fields, p_i is the ion pressure, φ is the electrostatic potential. $V_{\|}^{PS}$ is the Pfirsch-Schlueter velocity, calculated under the assumption that p_i and φ are the flux surface quantities. $V_{\|}^{E}$ is the velocity compensating the poloidal $\vec{E} \times \vec{B}$ drift in the radial electric field. The physics of these flows has been discussed in [7] and references therein. Note that these are simplified expressions. However, as was shown in [6], the parallel velocity from Eq. (2) is similar to that obtained in the simulations and has the same parametric dependence. The parallel velocity calculated according to Eq. (2) is also plotted in Fig. 2. As can be seen in the SOL 2-3cm outside the separatrix, analytical, simulated and measured parallel velocities are of the same order for presented shot as well as for other two shots.

On the basis of Eq. (2) one would expect the following parametric dependence of the parallel velocity in the SOL

$$V_{\|} = A \frac{T}{B_x}, \quad (5)$$

where A is some coefficient and T is the SOL average temperature. This scaling could be obtained from Eq. (2) assuming constant SOL width, $\varphi \sim T_e / e$ and $T_i \sim T_e$. No strong density or toroidal magnetic field dependence is expected.

The temperature dependence of the Mach number measured for the shots shown in Fig.1 is qualitatively consistent with the scaling: larger Mach numbers corresponds to larger SOL temperatures. To calculate the absolute values of the parallel velocity the Mach number should be multiplied by the sound speed. Since the ion temperature was not measured, the simulated ion and electron temperatures were used to calculate the sound speed. The absolute value of the parallel velocity at the reference point is shown in Fig. 3. One can see that an approximately linear rise with the parameter T / B_x is observed both for experimental and simulated velocities in accordance with the scaling Eq. (5).

In Fig. 4 the absolute value of the parallel velocity is plotted versus local values of the parameter T / B_x taken locally at the equatorial mid-plane for distances in the range 1-5 cm outside the separatrix. The shots №15214, №15226 were not included in this plot because they were simulated in similar, but not real geometry, and some parameters may not be consistent with the real discharges (especially profiles of T / B_x). Again the dependence may be approximated as a linear one in both the experiment and modeling.

3. Conclusions

Simulations with the B2SOLPS5.0 code reproduce the experimentally observed co-current rotation direction. The absolute values of the simulated Mach number are smaller than those of the measured ones; the difference is up to a factor of two. The simple analytical expression, Eqs. (2)-(4), is consistent with the measurements and simulations. The parallel velocity is increasing with temperature and decreasing with poloidal magnetic field as suggested by the scaling Eq. (5).

References

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