

PROMOTING ABRUPT PLASMA DENSITY PROFILE AND TRANSPORT  
BARRIER FORMATION

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It is shown that the amplitude of the electron radial oscillations is smaller for larger shear of electron angle velocity  $\partial_r \omega_{\theta 0}$  and for more abrupt plasma density profile  $n_{0e}(r)$ . It is shown that the maximal amplitude of the vortex is inversely proportional to the angular velocity shear. These dependences promote abrupt plasma density profile and internal transport barrier formation.

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INTRODUCTION

Now internal transport barrier (ITB) formation is widely investigated problem (see reviews [1-3]). Earlier the effect is considered, that shear of the particle angle velocity damps anomalous transport, separating the coherent ordered motion owing the relative shift of vortex layers. ITB is formed for under-threshold shear at well-known condition: the shearing rate  $\omega_{\vec{E} \times \vec{B}}$  exceeds the maximum linear growth rate  $\gamma_{\max}^{\text{lin}}$  of most unstable mode  $\omega_{\vec{E} \times \vec{B}} > \gamma_{\max}^{\text{lin}}$  (see reviews [1, 2]). We consider one more effect of decrease of the electron radial oscillations in vortical perturbation field, excited in inhomogeneous nuclear fusion plasma, located in crossed magnetic  $\vec{H}_0$  and radial electrical  $\vec{E}_{0r}$  fields, at increase of  $\partial_r \omega_{\theta 0}$  and  $\partial_r n_{0e}$ .

DEPENDENCES OF AMPLITUDE OF ELECTRON RADIAL OSCILLATIONS ON  
SHEAR AND PLASMA DENSITY PROFILE

The electron radial oscillations in vortical convective cells, excited in inhomogeneous nuclear fusion plasma in crossed magnetic and radial electrical fields, is described analytically. We use adiabatic approximation for electrons, because for high level of electron density perturbations  $\delta n_e$

azimuth deformation of the vortex due to shear of electron drift velocity in the crossed fields. One can derive from electron eq. of movement in adiabatic approximation the inverse dependence of radial width  $\delta r_v$  of separatrix of excited vortex on the shear of the electron angle velocity  $\partial_r \omega_{\theta 0}$  in crossed fields

$$\delta r_v \approx 2 \left[ \frac{2}{r_v m_e \omega_{ce}(r_v) |\partial_r \omega_{\theta 0}|_{r=r_v}} \left| e\phi_0 - \frac{\delta p_{e0}}{n_e(r_v)} \right| \right]^{1/2} \quad (1)$$

This dependence promotes ITB formation. Here  $\omega_{ce}$  is the electron cyclotron frequency;  $r_v$  is the radius of vortex localization;  $\phi_0$ ,  $\delta p_{e0}$  are the amplitudes of electric potential and electron pressure perturbation.  $e\phi_0 - \delta p_{e0}/n_e(r_v)$  can be connected with characteristic of electron vortical movement  $\alpha \equiv \vec{e}_z \text{rot} \vec{V}_e$  through

$$\alpha / V_{the} \rho_{ce} \approx e\Delta\phi / T_e - \Delta n_e / n_e, \quad (2)$$

derived from the electron eq. of movement.

Let us connect  $\delta r_v$  with  $\delta n_e$ . For that we use eq.

$$d_t [(\bar{\alpha} - \bar{\omega}_{ce}) / n_e] \approx 0, \quad d_t = \partial_t + (\vec{V}_\perp \vec{\nabla}_\perp) - V_{ph} \nabla_\theta, \quad (3)$$

obtained similar to [4] from electron eqs. of movement and continuity without any approximations for transversal electron movement with velocity  $\vec{V}_\perp$ .  $V_{ph}$  is the phase velocity of perturbation. From eq. (3) one can derive the inverse dependence of value of the electron radial oscillations  $\delta r$  on degree of steepness of the plasma density profile  $\partial_r n_{0e}$

$$\delta r(\theta, r) = - \frac{1}{\omega_{ceo} \partial_r (n_{0e} / \omega_{ce})} \delta n_e(\theta, r) \quad (4)$$

(1), (4) demonstrate that the amplitude of the electron radial oscillations for the given perturbation amplitude is smaller for larger  $\partial_r \omega_{\theta 0}$  and  $\partial_r n_{0e}$ . It results in mincing of excited vortical convective cells, to termination of their interaction, to decrease of their correlation, observed in [5]. The latter helps ITB formation.

The vortex is excited up to the amplitude, at which the layers, trapped by it, during excitation time  $\gamma^{-1}$  are shifted relative to each other due to angle velocity shear  $\delta r_v \partial_r \omega_{\theta 0} \Big|_{r=r_v}$  on the angle not larger  $2\pi/\ell_\theta$ , i.e.

$$(\ell_\theta / 2\pi) \delta r_v \partial_r \omega_{\theta 0} \Big|_{r=r_v} \leq \gamma. \quad (5)$$

$\delta r_v$  from (1), we estimate the maximal amplitude of the vortex

$$\left| e\phi_0 - \frac{\delta p_{e0}}{n_e(r_v)} \right| = \left( \frac{\gamma\pi}{\ell_\theta} \right)^2 \frac{r_v m_e \omega_{ce}}{2 \left| \partial_r \omega_{\theta 0} \right|_{r=r_v}} \quad (6)$$

The maximal amplitude is inversely proportional to the angular velocity shear.  $\gamma$  is the growth rate of instability development. It also promotes ITB formation, suppressing the radial transport especially in the case of small magnetic shear. It is determined by that small magnetic shear leads to large spatial interval  $\Delta$  between rational surfaces [6].

## CONCLUSIONS

It is shown in this paper in adiabatic approximation that the electron radial oscillations is smaller for larger shear of electron angle velocity in crossed fields. Also it is shown that the electron radial oscillations is smaller for more abrupt plasma density profile. The maximal amplitude of the excited vortices is inversely proportional to the angular velocity shear. These dependences promote ITB formation.

There are some effects, connected with shear. Under very unfavorable conditions, i.e. at strong anomalous transport, when it is determined by a streamer, formed by single wide vortex, which one overlaps all inhomogeneous area, the shear mince vortices. It leads to anomalous transport damping. Under more favourable conditions, i.e. at not strong anomalous transport, determined by lattice of vortices, the shear can spatially separate vortices. In this case the damping of anomalous transport is also realized.

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