Turbulence evolution in plasma shear flows

V.S. Mikhailenko[a], V.V. Mikhailenko[b], K.N. Stepanov[b]

[a] *Kharkov National University, 61108 Kharkov, Ukraine*
[b] *Institute of Plasma Physics of the National Science Center "Kharkov Institute of Physics and Technology", 61108 Kharkov, Ukraine*

vmikhailenko@kipt.kharkov.ua

The results of the comprehensive investigations of the linear and nonlinear turbulent mechanisms of the turbulence suppression in plasma shear flows are given. We have considered the sets of fluid equations, obtained in drift approximation, drift kinetic equation, the non-modal and renormalized nonlinear solution of the Vlasov - Poisson system for plasma flows with homogeneous velocity shear. Analysis is performed in time domain as the solution of the initial value problem without the spectral decomposition in time.
The investigation of the linearized Hasegawa-Wakatani (HW) system demonstrates, that in the convective frame of reference this system has solutions of the modal type with frequency and growth rate as for plasma without shear flow and without any manifestations of the inhomogeneous Doppler shift. In the laboratory frame of reference that mode is observed as a sheared mode with time depended wave number and frequency modified by inhomogeneous Doppler shift with nonseparable time-spatial dependence. It is obtained that with convective variables the $E \times B$ nonlinear convective term in nonlinear HW system appears to be free from any velocity shear effects. The renormalized nonlinear theory for HW system is developed. The nonlinear integral balance equation, which governs the process and level of the drift turbulence saturation is obtained. It determines the level of drift turbulence in a steady state, resulted from random turbulent motion of plasma in the unstable drift turbulence. We find that it does not include any effects associated with flow shear. The known effect of the enhanced dispersion of plasma displacements along shear flow presents the variance of the plasma displacements resulted from the above-mentioned shear modes in the laboratory frame. This effect has nothing in common with effect of the "suppression of the instability due to enhanced decorrelation by shear flow". The same conclusion is valid for other fluid models of plasma, obtained in drift approximation, in which all nonlinearities other than $E \times B$ nonlinearity are ignored.
The non-modal solution of the initial value problem to the linearized Vlasov-Poisson system for the magnetized plasma shear flow is presented. It is valid for any desired time and for velocity shear parameter, which may be comparable to drift waves frequency. Nonlinear renormalized theory is developed, which accounts for new combined effect of plasma turbulence and shear flow. That effect consists in turbulent scattering of ions across the shear flow into the regions with a greater or smaller flow velocity and resulted in enhanced by shear flow nonlinear resonances broadening.