LH-transition dynamics in a tokamak in the vicinity of GAM and pellet injection

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H-mode is a necessary operation regime for a tokamak-reactor. According to modern views, for the transition to H-mode (LH-transition) it is necessary to create a self-sustaining transport barrier – area of suppressed turbulent transport in the presence of strong inhomogeneous radial electric field. However, in some tokamaks despite the existence of such inhomogeneous Er, LH-transition is impossible; thus it is crucial to analyze the possibility and causes of transition to H-mode.

Tokamaks TUMAN-3M and FT-2 are conventional tokamaks that show characteristic geodesic acoustic mode (GAM) activity in the low density operating regimes, and GAM creates strong inhomogeneity of radial electric field, which could trigger LH-transition. In TUMAN-3M experiments GAM burst is always observed in low density regimes to precede the LH-transition, while in FT-2 transition never occurs despite the presence of GAM oscillations of significant amplitude. Also for TUMAN-3M it is possible to initiate LH-transition by means of creating steep peripheral density gradient during a pellet injection.

By means of gyrokinetic simulation of GAM qualitative and quantitative parameters of turbulence and turbulent transport were obtained in the both tokamaks; particularly, fast reaction of anomalous diffusion coefficient and particle and energy fluxes on electric field oscillations created by GAM were discovered.

Based on experimental data and gyrokinetic simulation results, we simulated plasma density evolution in TUMAN-3M and FT-2 in the presence of GAM oscillations. Simulation results show a good agreement with experimental observation. For TUMAN-3M LH-transition initiation occurs if GAM burst amplitude and duration exceeds a threshold value (GAM parameters were varied in a reasonable range near experimental ones): aside with oscillations of density gradient and radial electric field there was observed gradual increase of ne and Er mean values, leading to threshold value of electric field shear required for LH-transition. In case of pellet evaporation local and steep density gradient creates inhomogeneous radial electric field, which could lead to confinement improvement if peripheral ion temperature decrease is low enough. For FT-2 neither experimental GAM parameters, nor doubled amplitude and duration did not yield LH-transition initiation.

The analysis of non-linear particle flux dependence on density gradient helps to reveal possible causes of LH-transition presence or absence. Diffusion equation with radial electric field shear-dependent diffusion coefficient (and thus density gradient-dependent) in stationary case has (depending on particle source) either two stabile solutions (for L- and H-mode), or one – for one confinement mode only. The latter case, when the second stabile solution (H-mode) is impossible, corresponds to FT-2 characteristic discharge parameters; this is in agreement with experimental and numerical modeling results.

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