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Spontaneous and triggered abrupt and non-local reduction of electron heat and density fluxes and ITB formation in T-10 tokamak plasmas with ECRH/ECCD

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During non-local ("global") L-H transitions found in various regimes of JET and JT-60U tokamaks earlier [1-3], the rise of Te,i and ne starts simultaneously in the spatial zone ≈0.3< r/a <1, while heat and density fluxes fall simultaneously in the same region. At the ITB-events in JT-60U and T-10 (circular tokamak with a limiter =30 cm, R=150 см, Bт= 2.5 T), heat and density fluxes fall in a narrower internal spatial zone within ≈40-50% of the minor radius, see detail in [3-5].

The present report describes the new type of L-H transitions in plasmas with W-limiter and Li-coating called "semi-global". Te starts to rise simultaneously at 0.2 r/a<0.6 similar to its behavior during an ITB-event in JT-60U and T-10. The density rises in a wider zone ≈0.3 < r/a <1 similar to a non-local L-H transition. The electron heat flux abruptly reduces in the spatial zone 0.2 < r/a < ≈ 1. The gradual formation of ITB occurs after transition. The rise of Te in the internal part of plasmas was mentioned at L-H transitions in circular tokamaks with the limiter TUMAN-3, JIPP T-IIU and TEXT-U [6-8] (light cooling of the periphery, like in our cases, was mentioned also). The formation of ITB measured with Thomson scattering was reported in [6]. Nevertheless, analysis of the non-locality of the electron heat flux jump was not done in [6-8].

The one spontaneous semi-global L-H transition was briefly described by us at EC-2018 workshop [9]. The spontaneous transitions (including dithering one) are observed at simultaneous co+contr ECCD by 2 gyrontrons only (total power 1.4-1.5 MW). The presence of dithering transitions (up to 5 H-mode phases with 5-10 ms length) means that the power is near critical value. The figure 1(a) shows the typical evolution of Te(r,t), line-averaged central density and energy content W at spontaneous and triggered semi-global transitions. In this particular case, neon puffing starts 5 ms before transition (PECRH=0.85 MW, see experiments [10]) and puffing starts 15 ms before transition in the regime with higher density and EC-power [11]. The plasma-wall interaction falls (D-beta level drops), Te starts to rise at 0.2 < r/a<0.6 together with the rise of density and W. The density at the edge increases 30% faster compare with that of in the bulk plasmas. The transition triggered by neon puffing is not a transition to RI mode since the level of radiation losses is small enough (below ~25%) and just starts to rise before the transition. Figure 1 (b) represents the typical profile of the electron heat flux delta(G Te) at the transitions in all cases. In this case the transition at PEC=1.4 MW and co+co ECCD, was caused by spontaneous drop of Li-containing flake (jump of flux is constant in space up to the edge if one believe to ECE data at the periphery). In a contrast with [1-3], the rise of density is important at calculations of delta(G Te) profile at transitions on T-10 by simple expression [1-5]: delta(G Te (r))S(r)= 3/2{volume integral of delta[d(nTe)/ dt]}, S(r) –enclosed surface and delta[d(nTe)/ dt] is the jump of derivative at the time of transition with the evolution of delta(n(r,t)) calculated from data derived by 16 channels interferometer. The transport gradually varies in space and time after transition and leads to the formation of ITB as one can see on the figure 1(b) (typical case). The similar case in the plasmas with co+contr ECCD has been described recently in [12].

The authors of the paper [13] show that the rise of central Te at the injection of small carbon pellets at ASDEX-U is explained by strong stabilization of the trapped electron mode turbulence due to the measured fast significant flattening of the density profile in the internal part of plasma column. This explanation is not valid in our cases since the density just starts to rise gradually after transition (even at the drop of flake the density varies abruptly at the edge only).

The paper describes the new type of transition called "semi-global"L-H transition. Te starts to rise simultaneously at 0.2 < r/a<0.6 similar to its behavior during an ITB-event in JT-60U and T-10. The density rises in a wider zone ≈0.3 < r/a<1 similar to a global L-H transitions at JET and JT-60U and the electron diffusivity falls in the same zone. The electron heat flux abruptly reduces in the spatial zone 0.2 < r/a< ≈ 1. The spontaneous transitions (including dithering one) are observed at simultaneous co+contr ECCD by 2 gyrontrons only. New triggers of the transitions are neon gas puffing and spontaneous drop of the Li-containing flakes in various regimes of ECCD and EC-power (observed at n line av (0) < 3 10 19/m3, Bt =2.3-2.5 T, Ip=200-250 kA). By our up to date knowledge, transitions with the non-local reduction of heat flux has never been reported in the tokamaks with limiter. An abrupt increase of energy confinement time tau-E at the moment of the transition is equal to 10-20% (small value of H-factor is typical at circular tokamaks). The H mode continues up to the double value of tau-E. The accumulation of impurities is absent. The part of Te rise can be explained by the abrupt reduction of the convective electron heat flux 2.5TeGn due to the decay of electron density flux Gn at the time of transition.

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