

POSSIBILITY OF AN INTERNAL TRANSPORT BARRIER PRODUCING UNDER DOMINATING ELECTRON TRANSPORT IN THE T-10 TOKAMAK

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Experiments for investigation of the possibility of an Internal Transport Barrier (ITB) producing under dominating electron transport were carried out on T-10.

As it was shown on other tokamaks [1-3] a non-monotonous (possibly, it may be flat too) total current profile $j_{\text{tot}}(r)$ formation is essential condition for ITB producing. Such current profile was produced on T-10 by on-axis electron cyclotron current drive (ECCD) in opposite direction to the initial ohmic plasma current (COUNTER-CD).

Preliminary calculations were made by ASTRA transport code [4] and by TORAY code [5] for EC-current $j_{\text{cd}}(r)$ calculations. These calculations were made for broad range of plasma parameters: total plasma current $I_p=75\div 150$ kA, average density $\bar{n}_e=(0.7\div 1.5)\times 10^{19}$ m⁻³, absorbed power P_{ab} up to 1 MW. It was shown that:

- 1) It is possible to create the non-monotonous current profiles (therefore, and q) with reversed shear area in the plasma core ($r/a \leq 0.35$);
- 2) the q_{min} value is changed in a wide range from $q_{\text{min}}\sim 1.3$ to $q_{\text{min}}\sim 3$ by I_p alteration from $I_p=150$ kA to $I_p=75$ kA correspondingly.

The T-10 experiments were made at the mentioned above range of plasma and EC-power parameters. The toroidal magnetic field B_t were met to requirements of the exact on-axis power absorption ($B_t=2.42$ T). For all cases experiments were made in both COUNTER- and CO-CD regimes. It permitted to compare a confinement and transport in plasma core under the same conditions but at different $q(r)$ profiles: monotonous (at CO-CD) and reversed shear (at COUNTER-CD).

The results of these experiments were as follows.

1. The reversed shear $q(r)$ profile was formed in the experiments.

2. No obvious signs of ITB formation were observed at $(q_{\min})^{\text{calc}} \approx 1.3$ ($I_p=150$ kA) and reversed shear $q(r)$ profile. Central plasma temperatures $T_e^{\text{counter}}(0)=T_e^{\text{co}}(0)$ during the whole pulse (Fig. 1).

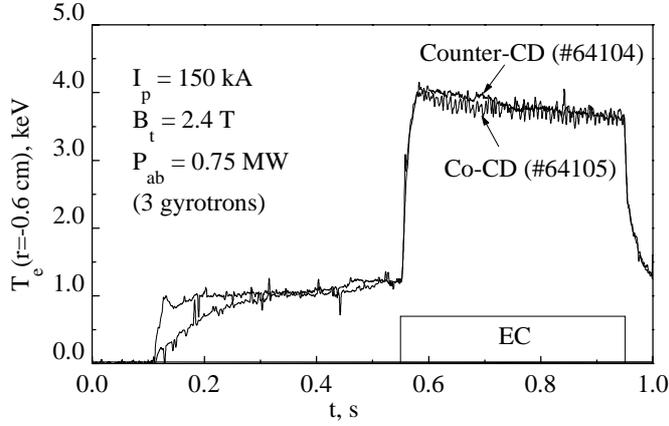
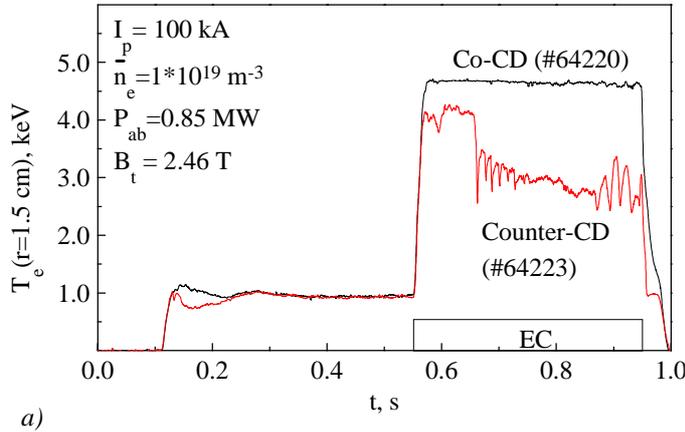
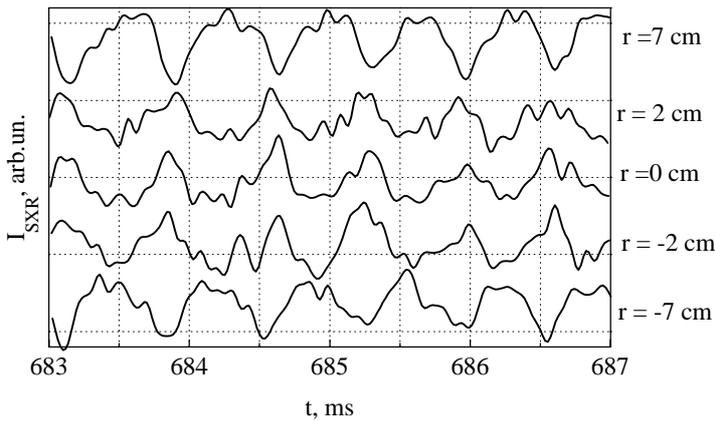


Fig. 1 The $T_e(0)$ traces in CO- and COUNTER-CD at $I_p=150$ kA;



a)



b)

Fig. 2. a) The $T_e(0)$ traces in CO- and COUNTER-CD at $I_p=100$ kA;

b) The soft X-ray intensity I_{SXR} traces.

3. When the q_{\min} increasing to ~ 2 (at $I_p=100$ kA, according to preliminary calculations) at the same EC-power the degradation of the central electron temperature $T_e(0)$ (\sim on 30 %) was observed at about 100 ms after EC-power turn-on (Fig. 2,a). This process was accompanied by MHD-activity of $m/n=2/1$ mode appearance (Fig. 2,b).

4. At the $(q_{\min})^{\text{calc}} > 2$ ($I_p=75$ kA) an initial (after EC-power turn-on) plasma behavior is analogous to the previous case ($T_e(0)$ degradation with $m/n=2/1$ mode development), but a new phenomenon was observed. The $T_e(0)$ restoration up to initial (before MHD-phase) level was took place after the typical MHD-phase (Fig. 3).

The next peculiarities are essential.

- The $T_e(0)$ restoration is observed after MHD phase always in all experiments examined.

- $T_e(0)$ value on restoration phase does not exceed initial (before MHD) value and remains about 10% lower than $T_e(0)$ at CO-CD (i.e. at monotonous $q(r)$ profile) as it is shown in Fig. 3.

- As it is seen from comparison of $I_{SXR}(r)$ profiles in both COUNTER-CD (after restoration) and CO-CD it is no obvious signs of temperature gradient steeping in vicinity of q_{min} (Fig. 4).

Therefore, $T_e(0)$ restoration observed in these experiments is not result of ITB formation.

For more detailed analysis the results of these experiments was examined with model mentioned above. Maximal approaching to experimental conditions was made: $n_e(r,t)$ and $T_e(0,t)$ from experiment were used. Dynamics of discharge was taken into account.

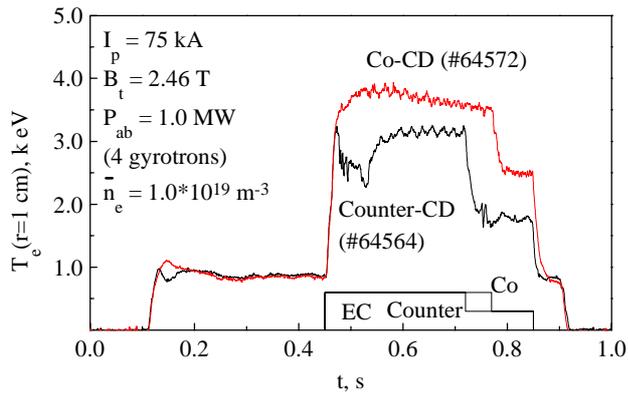


Fig. 3. $T_e(0)$ traces at CO- and COUNTER-CD at $I_p=75$ kA.

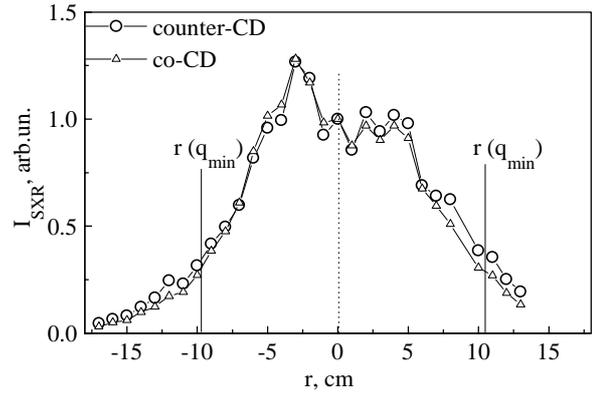


Fig. 4. Radial dependence $I_{SXR}(r)$ for COUNTER-CD after restoration and for CO-CD.

The results of the $q(r)$ calculations are shown on fig. 5,b. The experimental $T_e(0,t)$ trace is shown on fig. 5,a.

Comparison of the $q(r)$ profiles with plasma behavior in different time moments shows that the $T_e(0)$ degradation in experiment coincides with the moment of the second rational surface $q=2$ appearance. The restoration phase start is in a good agreement with the moment when the $q(r)$ profile crosses $q_{min}=2$ (Fig. 5,a).

This agreement between calculation results and experimental data gives foundation for more probable hypothesis of the restoration phenomenon. It is as follows. When the second rational surface $q=2$ appearances in plasma, an interaction between to islands $m=2/n=1$ formed near these surfaces becomes possible [6]. It leads to additional transport losses from plasma core and, therefore to $T_e(0)$ degradation (which is observed in experiment). The restoration phase beginning when q_{min} exceeds 2 and hence the conditions for additional electron transport connected with this MHD activity vanishes.

The experimental results and their numerical simulations allow us to conclude:

1. The reversed shear area in the plasma core ($r/a \leq 0.35$) in experiments with COUNTER-ECCD on T-10 has been formed.
2. In spite of reversed shear area producing there are no obvious signs of ITB formation. This is very significant for theoretical explanation of ITB physics.
3. $T_e(0)$ degradation is connected, apparently, with appearance of the additional transport losses because MHD-activity.
4. Profiles $q(r)$ with two resonance surfaces becomes dangerous for plasma confinement when q_{\min} becomes close to $q_{\min} \approx 2$.

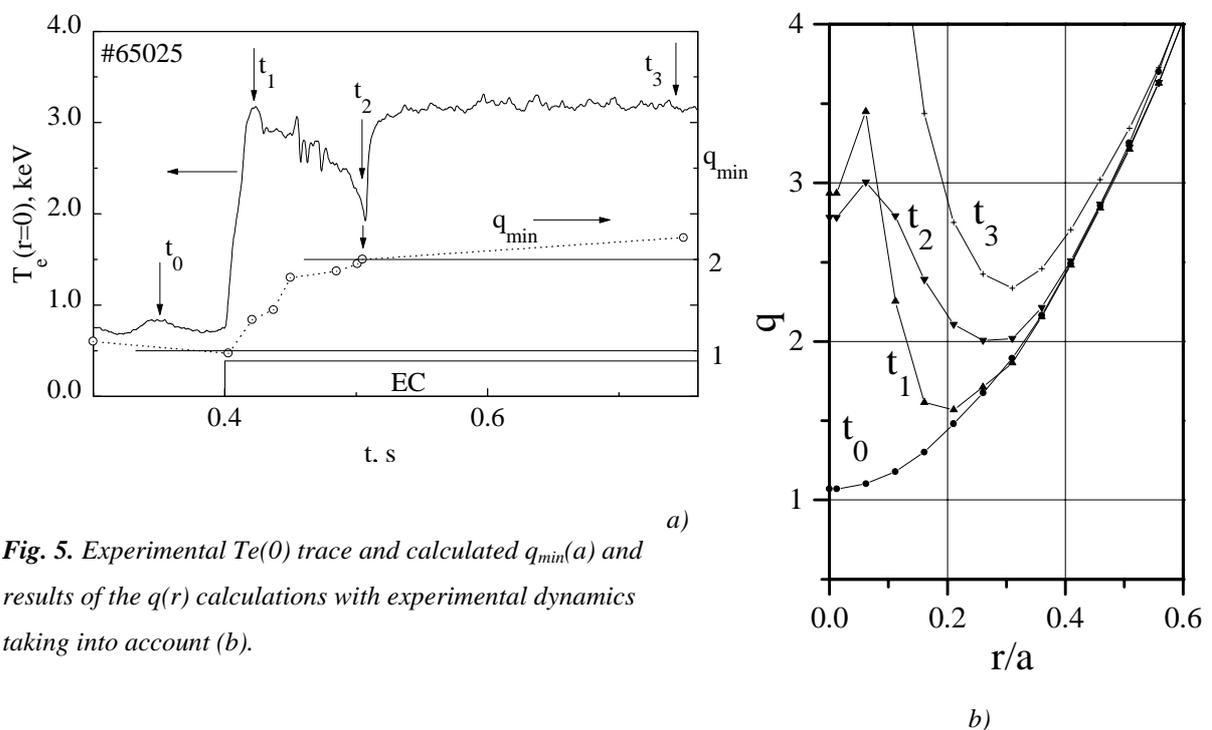


Fig. 5. Experimental $T_e(0)$ trace and calculated $q_{\min}(a)$ and results of the $q(r)$ calculations with experimental dynamics taking into account (b).

Acknowledgements

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