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Confinement Bifurcations by Poloidal Magnetic Flux Perturbations in the TUMAN-3M

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Motivation

In earlier experiments performed in the TUMAN-3M tokamak, the possibility of switching on/off the ohmic *H*-mode by poloidal magnetic flux perturbations has been found [1]. The flux perturbations were created by fast current ramp up/down or by magnetic compression produced by fast increase in the toroidal magnetic field. It was found that the current ramp up and magnetic compression are reliable means of *H*-mode triggering. The both scenarios are characterized by a positive perturbation of the poloidal flux. If a negative flux perturbation (current ramp down scenario) is applied, the *H*-mode terminated. In the recent experiments, another possibility of a negative flux perturbation was explored: the magnetic decompression. In agreement with earlier observations, the negative perturbation of the poloidal flux in decompression scenario resulted in *H*-mode termination.

There is a variety of mechanisms, which might be involved in the *L-H* and *H-L* transitions physics in the flux perturbation experiments. These are generation of a sheared E×B flow, increase/decrease in the input power, modifications of the edge current density and magnetic shear. Experimental observations and analysis of the role of different mechanisms in the transitions between confinement modes in the above experiments are presented in the paper. The observations can be understood in the terms of the model of a sheared radial electric field generation, which takes into account the electron Ware drift in a perturbed longitudinal electric field δE_φ [2].

Magnetic decompression experiments in the *L* and *H*-modes

The magnetic decompression (MDC) was performed by rapidly lowering the toroidal magnetic field. In the described experiment, the typical decompression ratio B_t^{DC}/B_t^{OH} = 0.75-0.8, and the time of field decrease τ^{DC} = 1.5-1.7 ms, which is small compared with the current penetration time $\tau_I \cong 30$ ms. Decompression resulted in a decrease in the poloidal flux and the corresponding negative perturbation of the loop voltage. In these regimes, the plasma current was kept constant, I_p = 120 kA. The MDC was applied to the ohmic *H*-mode and to the ohmically heated (*L*-mode) plasmas. Typical waveforms of some plasma

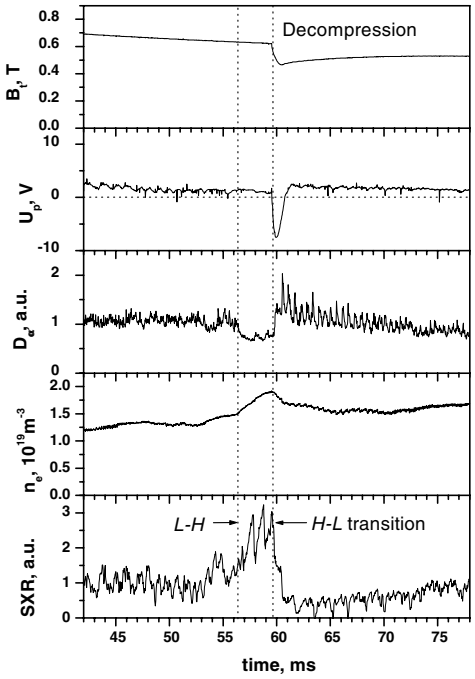

Fig.1. Waveforms of the toroidal magnetic field – B_t, loop voltage – U_p, working gas emission – D_α, average electron density – n_e and soft X-ray emission – SXR in a discharge with the *H-L* transition during magnetic decompression, I_p=120 kA.

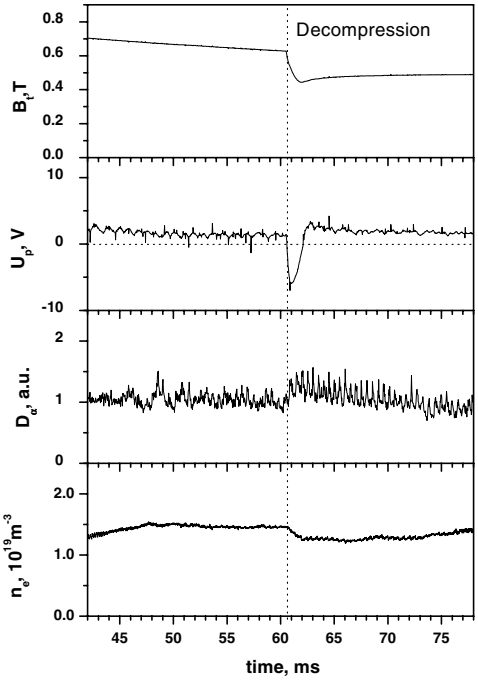

Fig.2. Waveforms of the toroidal magnetic field – B_t, loop voltage – U_p, working gas emission – D_α and average electron density – n_e in a discharge with *L*-mode preservation during magnetic decompression, I_p=120 kA.

parameters in the discharges with MDC are shown in Figs.1&2. Noteworthy is a strong negative spike in the loop voltage trace, observed during B_t decrease.

Decompression in the ohmic *H*-mode (Fig.1) led to a clear *H-L* transition, with the density and SXR emission intensity rise termination and D_α intensity increase. A simultaneous increase in the high frequency density fluctuation intensity was observed by reflectometry. No confinement bifurcation was found in the MDC scenario in the ordinary ohmic regime, see Fig.2. Only a small steplike decrease in the density and SXR emission was observed. The decrease is attributed to adiabatic expansion and cooling during the MDC. The results obtained in the MDC experiments are in agreement with the previous observations of the transitions between confinement modes in the presence of a poloidal flux perturbations (i.e. current ramp up/down and magnetic compression). In all experimental scenarios an increase in the poloidal flux results in the *L-H* transition or *H*-mode preservation, whereas decrease in the flux leads to the *H-L* transition or *L*-mode preservation.

Discussion

Two methods of magnetic flux perturbation – current ramps and magnetic compression/decompression, were used to trigger transitions between confinement modes in

the TUMAN-3M. The both methods produce essential perturbation on the different edge parameters, which might be involved in the *L-H* and *H-L* transition physics: toroidal electric field E_φ, current density j(r), magnetic shear $\hat{s}=(r/q)(\partial q/\partial r)$, input power P_{input}. The effect of poloidal flux perturbation on the above parameters and results of its action are summarized in Table 1.

First column of the table presents initial state of confinement in the described experiments. In the second column the type of applied perturbation is given. The sign of the edge E_φ is presented in the third column. In the columns 4, 5 and 6 the results of transport simulations using ASTRA code [3] are given: the qualitative estimation of j(r) evolution, the change in the edge $\hat{s}$ and the evolution of P_{input}. Last column contains observed result of the flux perturbation.

Table 1. Effect of poloidal flux perturbation on the confinement

Initial state	Scenario	Perturbation				Effect on confinement
		E_φ	J(r)	Edge $\hat{s}$	P_{input}	
L	CRU^{I}	**positive**	broadening	25% drop	**increase 45%**	***L* → *H***
H	CRU^{I}	**positive**	broadening	30% drop	**increase 45%**	***H* → *H***
L	CRD^{II}	**negative**	narrowing	35% rise	**decrease 30%**	***L* → *L***
H	CRD^{II}	**negative**	narrowing	40% rise	**decrease 25%**	***H* → *L***
L	MC^{III}	**positive**	narrowing	5% rise	**increase 15%**	***L* → *H***
H	MC^{III}	**positive**	narrowing	5% rise	**increase 10%**	***H* → *H***
L	MDC^{IV}	**negative**	broadening	10% drop	**decrease 15%**	***L* → *L***
H	MDC^{IV}	**negative**	broadening	10% drop	**decrease 10%**	***H* → *L***

^{I} – current ramp up,
^{II} – current ramp down,
^{III} – magnetic compression,
^{IV} – magn. decompression

Presented data indicate that no correlation exists between the result of the flux perturbation and both the j(r) evolution and the $\hat{s}$ evolution. Some correlation between the direction of confinement bifurcation and the change in the P_{input} exists: more power input – *H*-mode develops or sustains, less power input – *H*-mode terminates or *L*-mode sustains. This observation shows that the changes in the input power could help to trigger *L-H* and *H-L* transitions. The effect of P_{input} on the *L-H* transition was explored in the earlier experiments without flux perturbation. In those experiments the ohmic *H*-mode transition was observed at very different P_{input} [4]. The *L-H* transition was found in some shots with P_{input} being as low as 130 kW, whereas in other shots the *L*-mode was preserved up to $P_{input} \cong$

420 kW. This means the input power is unlikely to be the main factor controlling the transitions in TUMAN-3M.

The direction of confinement bifurcation correlates with the sign of the E_φ perturbation: positive δE_φ causes the *L-H* transition or preserves the *H*-mode. To the contrary, negative δE_φ leads to the *H-L* transition or preserves the *L*-mode. This behavior can be understood in the terms of the model of radial electric field generation, which takes into account the non-ambipolar electron Ware drift in a perturbed toroidal electric field δE_φ [2]. In this consideration, the ion Ware drift is neglected because of the high ion collisionality at the edge of TUMAN-3M. Since the Ware drift is proportional to E_φ/B_θ, the direction of the radial current of banana electrons depends on the toroidal electric field direction. Condition of zero total radial current leads to E_r emerging. The model predicts that positive δE_φ causes negative (inward directed) E_r and vice versa. Arising inwards/outwards directed E_r increases/decreases E_r shear and helps to trigger/terminate the *H*-mode. Thus, the mechanism suggests that the peripheral E_φ affects the transition processes. The observed directions of bifurcation correspond to the model predictions.

Summary

It was found that the negative perturbation of the poloidal flux produced by magnetic decompression results in the *H-L* transition or *L*-mode preservation. This observation is in agreement with the earlier experiments on flux perturbations by current ramp up/down and by magnetic compression. The *L-H* and *H-L* transitions in the flux perturbation experiments in the TUMAN-3M can be interpreted in terms of the model of a sheared radial electric field generation in the presence of perturbed longitudinal electric field.

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References:

[1] L. Askinazi, et al, J. Plasma & Fusion Res. SERIES, V.4 (2001), p.224.

[2] V. Rozhansky, et al, Control. Fusion and Plasma Phys. (Proc. 25th EPS Conf., Praha, 1998), EPS, Geneva (1998).

[3] Dnestrovsky A.Yu., et al, Preprint IAE-5358/6 (1991).

[4] Andrejko M.V., et al, Fusion Energy 1996, (Proc. 16th IAEA Conf., Montreal, 1996), IAEA, Vienna (1997), Vol.1, 891.