ROLE OF WALL IN THE LOW FREQUENCY MHD ACTIVITY EVOLUTION IN THE TUMAN-3M TOKAMAK

S.V. Lebedev, L.G. Askinazi, M.I. Vild'junas, V.E. Golant, *M.P. Gryaznevich, N.A. Zhubr, V.A. Kornev, S.V. Krikunov, V.V. Rozhdestvensky, E.A. Shevkin, A.S. Tukachinsky

Ioffe Physico-Technical Institute, RAS, St.-Petersburg, Russia

**Culham Science Centre UK AEA, Abingdon, United Kingdom*

Experimental observation of the MHD oscillations evolution

MHD activity with strong frequency variation was observed under certain experimental conditions in the ohmically heated TUMAN-3M tokamak (R_0=0.53 m, a_l=0.22 m, B_t=0.8 T, I_p=140 kA, n_{av}=(1-5) 10^{19} m^{-3}, $T_e(0)$=0.4-0.6 keV, $T_i(0)$=0.1-0.2 keV). As a rule, the MHD oscillations appear in the end of current ramp phase, see Fig.1. Density ramp up at this stage leads to the strong increase in the MHD amplitude. Typical frequency range of the oscillations is 0.5-8 kHz. The activity starts with low amplitude and high frequency, f=6-8 kHz. In the time-scale of 5-10 ms the mode amplitude grows substantially. Simultaneously, the frequency dramatically decreases to 0.5-1.5 kHz. In many cases the

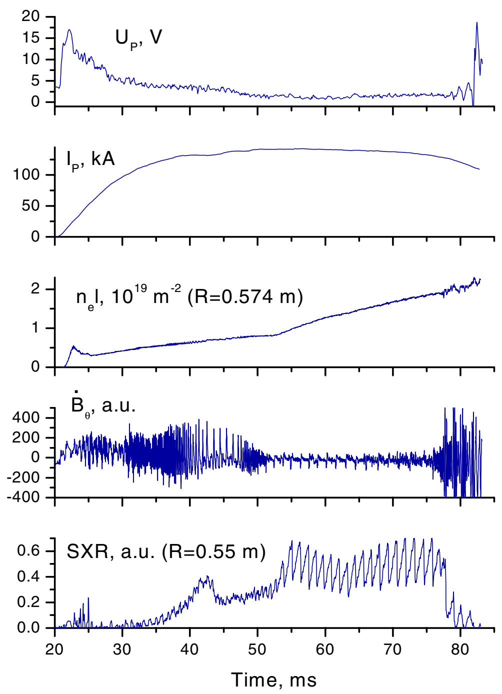

Fig.1. Waveforms of the main plasma parameters in the shot with m=4 MHD oscillations in the end of current ramp phase.

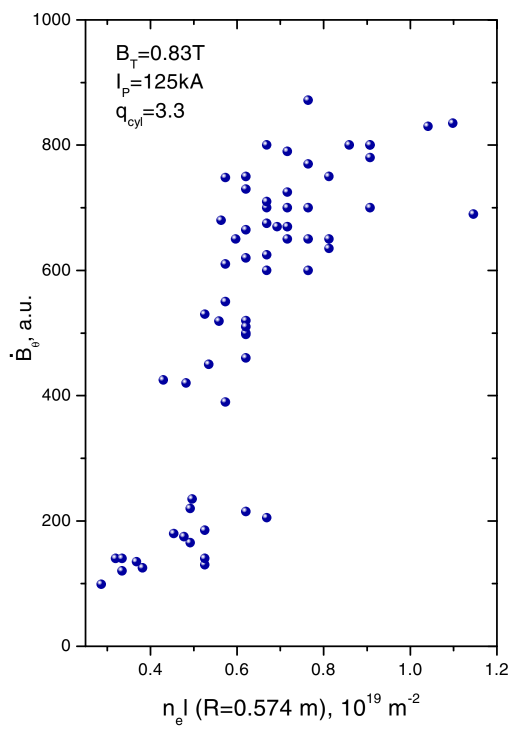

Fig.2. Dependence of the MHD oscillation amplitude on the chord-integrated density.

development of the MHD activity resulted in the mode locking followed by major disruption. In some shots disruption does not occur, instead a gradual decay of the perturbation takes place: frequency increases and amplitude drops to a complete stabilization, as seen on Fig.1.

The oscillations are observed using various diagnostic tools. Set of 24 pick-up Mirnov coils allows identification of the poloidal mode number. In majority of observed cases the mode number was 4, although m=3 was measured occasionally. The MHD amplitude strongly depends on density. Figure 2 presents dependence of the amplitude of Mirnov coil signal on density measured by microwave interferometer in the set of similar shots. In the conditions of the ohmic heating, energy content appears to be proportional to the density. Therefore increase in the mode amplitude with density could not be distinguished from beta dependence, although β_N values are well below ideal limit for TUMAN-3M circular plasma. In the discussed shots the maximum β_N did not exceed 1.0.

The other feature of the observed oscillations is the strong modulation of the chord-integrated density with the MHD frequency. The modulation is seen on all chords including central and peripheral ones. Evolution of the microwave interferometer signals along vertical

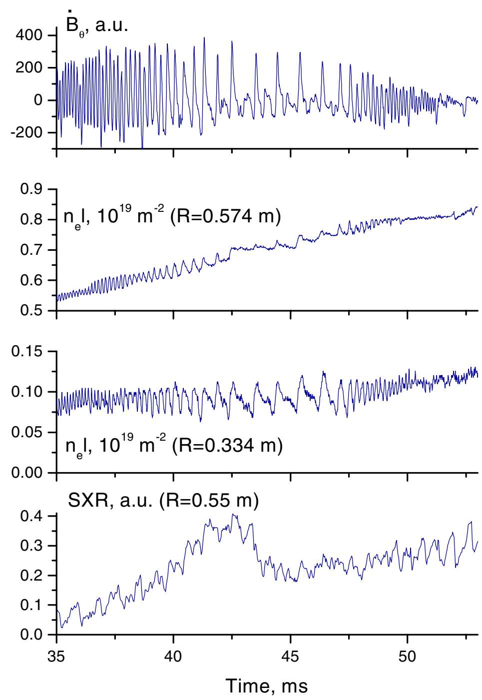

Fig.3. Evolution of MHD oscillations on Mirnov coil, interferometer signals and soft X-ray detector.

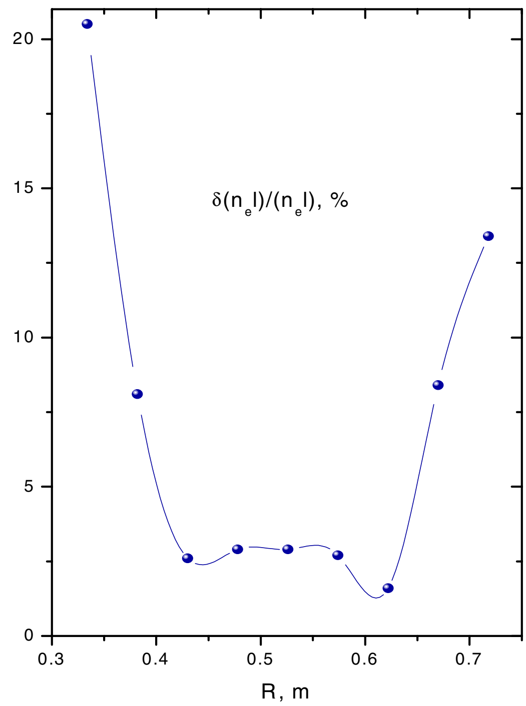

Fig.4. Relative amplitude of the line-integrated density perturbation as a function of major radius.

chords with R=0.574 m and R=0.334 m is shown on Fig.3 (measured in the shot presented on Fig.1). Relative amplitude of the density perturbation as function of major radius is shown on Fig.4. Note the amplitude of the modulation near periphery is as high as 20%. The same frequency is seen on the central soft X-ray detector signal. If the mode evolves without disruption (unlocks, accelerates and damps), the SXR signal slowly decays indicating rearrangement of the plasma interior. The time-scale of the rearrangement is 1-2 ms, which is much longer than the minor disruption time-scale, see Fig.3.

Measurement of the density modulation along 9 vertical chords allowed estimation of the density variation within island structure. Details of the simulation are given in the next section. The simulation gives island width of approximately 2 cm, resonance surface radius – 20 cm and maximum density in the O-point – (0.5-0.7) 10^{19} m^{-3}. Estimated from these data density gradient inside magnetic island ∇n_{island}=(5-7) 10^{20} m^{-4}, what is by a factor of ~ 10 higher than ∇n nearby resonance surface obtained from profile measurement. This might be considered as indication of perfect confinement properties inside magnetic island. This phenomenon reminds good confinement inside filaments reported by RTP [1].

Simulation of the mode structure using interferometry data

The full set of interferometry data was used to simulate the magnetic structure parameters: poloidal number – m, island width – w, resonance surface radius – r_S and amplitude of density perturbation – n_{island}. Gaussian shape of perturbation (in both radial and poloidal directions) was assumed. The rotating perturbation was integrated along different chords and method of least squares was applied to chose m, w, r_S and n_{island}. Comparison of the simulation results and experimental data for the amplitudes of the perturbations at different major radii is shown on Fig.5. In this case m=4, w=1,8 cm, r_S=20,2 cm and n_{island}= 0.5 10^{19} m^{-3}. Results of simulations are in qualitative agreement with experiment: both curves have two minima at close radial positions. Differences in positions of outer minima and in amplitudes near the center are thought to be explained by underestimation of the toroidicity in the simulation. Further work should be done to check this assumption.

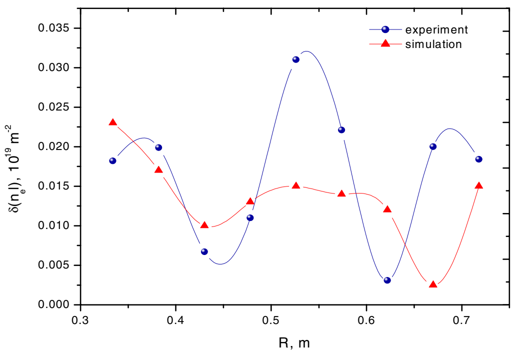

Fig.5.Measured and simulated amplitudes of chord-integrated density perturbations.

Discussion of wall effect on MHD evolution

Observed evolution of the mode frequency and amplitude has two features, which have to be explained. The first is the slowing down of the mode accompanied by amplitude increase. The vessel wall of TUMAN-3M is thin (δ=1.2 mm) and made of Inconel having high resistance, therefore it was not clear is it enough drag to account for locking. Other feature spontaneous mode acceleration and amplitude diminishing, which looks inexplicable for the mode, which is nearly locked.

In order to estimate effect of wall in mode locking a characteristic time of the wall τ_W was calculated using model [2]. For the realistic geometry of TUMAN-3M $\tau_W \approx 7.5$ ms, which is close to the typical deceleration time τ_{dec} in the initial phase of locking. As it is seen on Fig.3, the τ_{dec}=5-10 ms. Thus, the wall can provide enough drag for the mode locking.

A key factor for understanding the reason for the mode acceleration and damping is SXR behavior in the lock phase. Figure 3 demonstrates slow (with time-scale of 1-2 ms) decay of SXR emission indicating interior rearrangement. During this process a noticeable change in the current density profile occurs. The prove of current profile redistribution could be found on loop voltage trace, which is presented on Fig.1. The drop of U_p on 45 ms manifests current penetration in the plasma interior and sharpening of the j(r). The keen j(r) is helpful for tearing mode stability [3]. We assume the mode damps due to drive disappearance. The above model of j(r) evolution was confirmed by transport simulation [4].

Summary

MHD activity with strong frequency variation was observed in the ohmically heated TUMAN-3M tokamak. Estimated density gradient inside magnetic island is by a factor of ~ 10 higher than ∇n obtained from profile measurement. That might be considered as indication of perfect confinement properties inside magnetic island. The thin TUMAN-3M wall can provide necessary drag for the mode locking. Sharpening of the j(r) in the end of current ramp phase is thought to account for increase in the tearing mode stability, thus resulting in the mode unlocking and damping.

Acknowledgements

The work was supported by RFBR. Grants Nos 00-02016879, 00-15-96760

References

[1] N.J. Lopes Cardozo, PP&CF, **39** (1997), B303
[2] R. Fitzpatrick, Nuclear Fusion, **33** (1993), 1049
[3] P.H. Rutherford, Physics of Fluids, **16** (1973), 1903
[4] M.V. Andreiko, et al, Plasma Physics Reports, **26** (2000), 191