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ABSTRACT

The influence of resonant helical perturbations on the plasma confined by the small tokamak TBR-1 was experimentally investigated. Strong attenuations of the Mirnov oscillations could be easily obtained by activating different resonant helical windings. The amplitudes of these oscillations were restored as the helical perturbation ended.

INTRODUCTION

Since the first work on Pulsator, resonant helical windings (rhw) have been widely used in other tokamaks to generate helical perturbations. Experiments with rhw showed that macroscopic oscillations can be controlled and the nature of the disruptive instabilities can therefore be investigated(1,2). The ergodization of the plasma periphery, in order to control the edge plasma parameters(3), and the detailed observations of the global modes in the tokamak discharges can also be achieved by using rhw configurations(4).

The influence of rhw perturbations on the plasma confinement was also investigated in the small low-beta tokamak TBR-1 of the Institute of Physics of the University of São Paulo. The major and minor radii of this device are 0.30m and 0.11m and the radius at the limiter is $a \approx 0.08$m. The toroidal magnetic field ranges from 0.40T to 0.45T, the plasma current I_p from 6kA to 12kA, the mean electron density is $\bar{n} \approx 5 \times 10^{18} m^{-3}$ and the central electron temperature is $T_o \approx 200$eV. The windings are externally positioned around the torus in such a way they circle the vessel completely. Their helicity can be selected to produce perturbations with n=1 and m=2,3 or 4. The corresponding resonant helical field, created by the current I_{hel} in the coils (with opposite directions in adjacent conductors equally spaced), has a well defined and dominant harmonic component (fig. 1) of the form $\cos(m\theta - n\phi)$ where θ and ϕ are the poloidal and toroidal angles, respectively. Two different pulse shapes of the helical current were used in this work.

EXPERIMENTAL SET UP AND MEASUREMENTS

The general confinement and stability conditions of the plasma in the TBR-1 tokamak and the main characteristics of the detected Mirnov oscillations were reported previously(5). The equilibrium is mantained by a programed external vertical field. Feedback control of the plasma position is not available yet and some horizontal plasma displacements occur during the discharges. The mhd activity is usually intense and easily detected during the first three miliseconds, when the plasma is less sensi tive to disruptive instabilities. The poloidal magnetic field oscillations $\dot{\tilde{B}}_\theta$ were detected through 16 coils equally spaced in the poloidal direction and 4 in the toroidal direction. The main detected modes were characterized by wave numbers m=2, 3, 4 and n=1, with frequencies ranging from 30 to 90 kHz.

The experimental results obtained with a m = 3 / n = 1 helical winding and a current of 185A are shown in fig. 2. The coils were activated 0,3ms before the plasma discharge. The main observed effect was a strong reduction of the mhd activity and this was noticeable mainly during the first 1,5ms of the discharge. After this period an inward displacement is often observed and the activation of the helical coils tends to anticipate this displacement. This might be related to the instability against horizontal motions(6).

For a current distribution $j=j_o[(1-r/a)^2]^{1.4}$, which corresponds to q(a)=3.8, the island width of the 3/1 mode was about two times larger than that obtained after the windings were activated(7). The 3/1 coil has also a small m=2 component and attenuation of both the dominant m=3 and the sideband m=2 were obtained.The stochasticity parameter decreased from 0.5 to 0.3 with the activation of the coil.Field line tracing calculations for the modified equilibria with the helical windings show large dirtorted magnetic islands with large ergodic regions(7). The reduction of the mhd activity is probably due to a plasma response to the external resonant perturbation applied rather than a consequent magnetic surface break-up.

An increase of the oscillation frequency associated with an amplitude attenuation was often observed during the activation of the coil (fig. 3). This behaviour agrees with the property of the Mirnov oscillation observed in the TEXT Tokamak(8).

In fig. 4, it is shown the effect caused on the Mirnov oscillations by the activation of a 2/1 helical current with 260A of amplitude and duration of 3ms. Again in this case, in which a square wave like current pulse is created, an inward displacement of the plasma column is verified. The poloidal perturbation field $\tilde{B}_\theta/B_\theta$ measured before and after the raise of the current pulse was about (1,3 ± 0,3)% and (0,8 ± 0,2)%, respectively, for the 2/1 mode.

Shortening up the current pulse duration to 0.75ms, the attenuation of the mhd activity is once again obtained as it

is shown in fig. 5. After the end of the pulse, once the resonant helical field influence at the plasma ceases, the initial intensity of the oscillations is promptly restored. The time lag observed between the current pulse formation at the helical windings and the attenuation of the mhd activity ($\sim$200μs) is consistent with the time penetration field through the steel wall of the vessel (3.1mm thick).

Fourier analyses calculation of the relative amplitude of the perturbed poloidal field for three different time ranges of the discharge, i.e., before, during and after the current pulse application on the rhw was performed.Right before the plasma is effectively submited to the external field influence , it could be verified that $\tilde{B}_\theta/B_\theta \sim (0,7 \pm 0,2)\%$. The dominant modes, with almost the same amplitudes, were m=3 and m=4, plus a small contribution of m=2. During the next part the poloidal field oscillations become weaker with $\tilde{B}_\theta/B_\theta \sim (0,3 \pm 0,1)\%$ and the dominant mhd mode is essentially m=3. Finaly, in the last region, the mhd amplitude grows up again (with a growth rate $\gamma \approx (4,3 \pm 0,6) \times 10^4 s^{-1}$) which corresponds almost entirely to the saturated m=2 component. It was also seen that the oscillations detected during the activation of the rwh still had n=1 only. The frequencies associated with these three parts of the discharge were observed to have values of approximately 65kHz and 45kHz and 30kHz, respectively.

Finally, the coils were used as passive helical windings for the detection of particular mode structures. The frequencies of the detected oscillations were the same for all periodic structures with different m and the same n=1.

CONCLUSIONS

The application of low intensity resonant helical fields ($I_{hel}/I_p \approx 2 - 3\%$) have shown to be an efficient method for attenuating and so for controlling the mhd oscillations in the small low β TBR-1 tokamak.

Fourier analysis of the magnetic pick-up coils' signals before, during and after the 2/1 helical pulse formation showed that the resonant field probably acted directly on the q=2 island. This is supported by the fact that the m=2 mode was observed only before and after the application of the helical windings. The pulse in fig. 5 illustrates very well this situation. The phenomenologial mechanism through wich the external field acts on the magnetic islands inside the plasma is not understood yet. A possible explanation could be a change in the current density profile caused directly by the m/n resonant fields on the magnetic islands of the same helicity. However, this consideration could not explain why the activation of a 3/1 helical winding could inhibit or produce sawteeth oscillations(4) since this fluctuation is well known to be related with the 1/1 oscillation mode.

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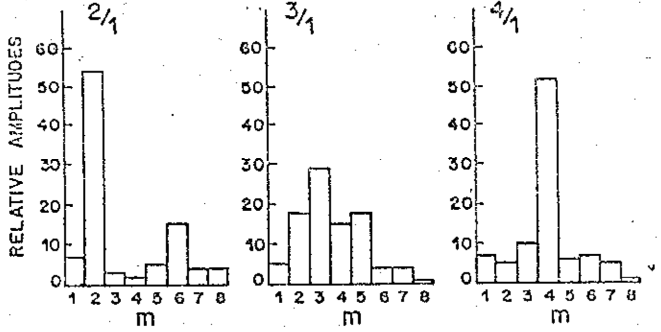

FIG. 1 - Fourier spectra associated with each m/n helical winding arrangement used in this work.

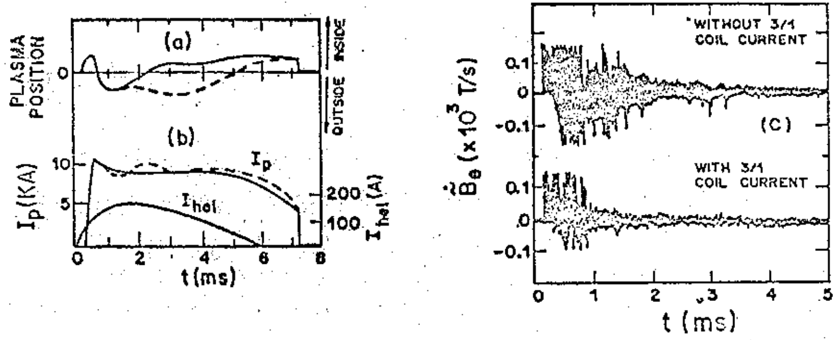

Fig. 2 - In (a) it is shown the horizontal position of the plasma column and in (b) the plasma helical current time profiles are presented. The full line (——)corresponds to the discharge with 3/1 helical winding activated.In (c) the corresponding mhd activity is shown.

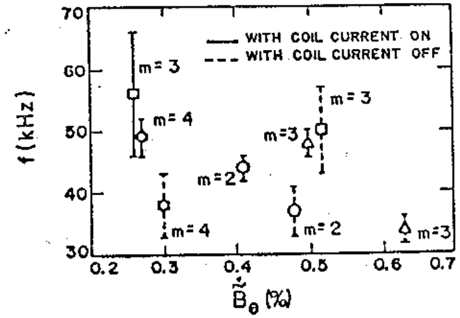

Fig. 3 - Dependence of the frequency with the normalized amplitude of the Mirnov oscillations.

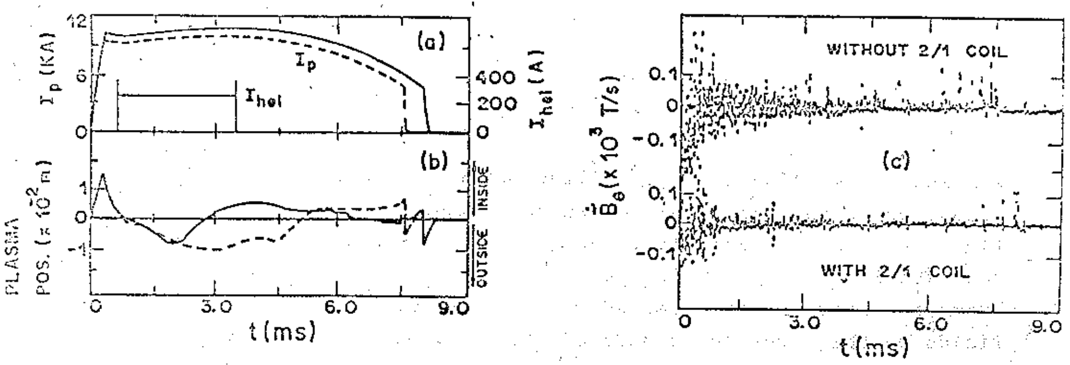

Fig. 4 - Curves in(a)show the plasma and helical current time profiles and in (b) the horizontal position displacements are shown. The full line (——) corresponds to the discharge in which the 2/1 helical winding was activated. In (c) the corresponding mhd signals are presented.

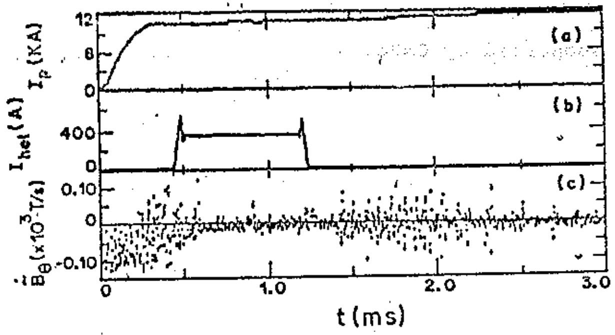

Fig. 5 - Profiles of plasma (a) and 2/1 helical windings (b)currents,during a discharge in the TBR-1. In (c) the corresponding mhd activity is presented.