STRUCTURE OF MHD FLUCTUATIONS IN THE TORSATRON U-3M IN STEADY-STATE STAGE OF DISCHARGE

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Study of MHD fluctuations was performed in quasi-stationary mode of weakly collisional discharge in torsatron U-3M in frequency range 0.5…70 kHz. The fluctuations of the magnetic field were detected in the following frequency ranges: 2.5…3.9, 5.9…7.2, 9.4…10.9, 14…15.9, 20…27, 39…47 kHz. It is also shown that there are standing and rotation structures. Rotation structures can rotate in the direction of both ion and electron diamagnetic drift. The poloidal structure of plasma MHD activity with wave numbers m=0; 1; 2; 3 was obtained, which made it possible to determine the level of fluctuations of the magnetic field inside the confinement volume.

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INTRODUCTION

The work [1] shows the results of MHD fluctuation studies of poloidal component of magnetic field in torsatron U-3M using 15 magnetic probes arranged out of the confinement volume (average radius with extreme magnetic surface a=10 cm, radius of measurement surface is r_{pr}=16.8 cm) during the stage of increase of current and plasma energy content. The work [2] shows that during this discharge stage the MGD fluctuations influence essentially the behavior of plasma. The work [1] offers procedures to study the spatial structure of non-stationary collisions that are developed in the investigated discharge.

The purpose of this work is to study the structure of MGD fluctuations of magnetic field at quasi-stationary stage of discharge based on procedures proposed in the work [1] within frequency range 0.5…70 kHz.

MAIN RESULTS

Temporal behavior of signal from one of 15 probes is given in the Fig. 1. Fig. 1,a shows general behavior of signal during discharge and Fig. 1,b shows the behavior of the signal registered during quasi-stationary stage of discharge during 3 ms (45…..48 ms). From the Fig. 1,b it is clear that the behavior of fluctuations has purely non-stationary character.

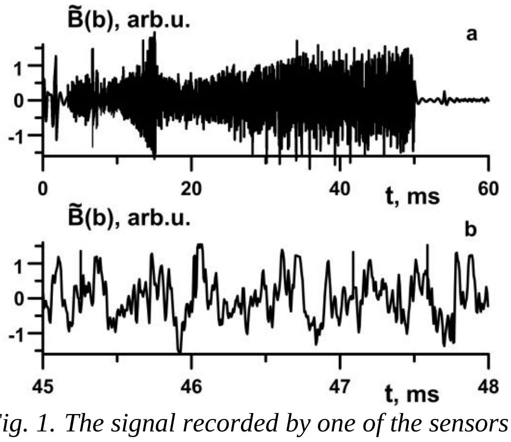

Fig. 1. The signal recorded by one of the sensors (probe # 10). a) full signal; b) signal in the range of 45...48 ms at the quasistationary stage of discharge

Analysis showed that fluctuations exist in the following frequency ranges: 2.5…3.9, 5.9…7.2, 9.4…10.9, 14…15.9, 20…27, 39…47 kHz.

We consider the spatial structure of plasma current collisions as Fourier series with poloidal wave numbers m. Using 15 azimuth asymmetrically set probes we can confidently identify fluctuations with poloidal wave numbers m=0; 1; 2; 3. For higher values of m ≥4 the error increases considerably. Typical for all frequencies is distribution of fluctuation amplitudes depending on the mode number is given in Fig. 2. Here we use the results of calculations of fluctuation values near the boundary of plasma cord (r=8.4 cm) within the frequency range 5.9…7.2 kHz. It is clear that the largest in magnitude are oscillations with m = 2, 3.

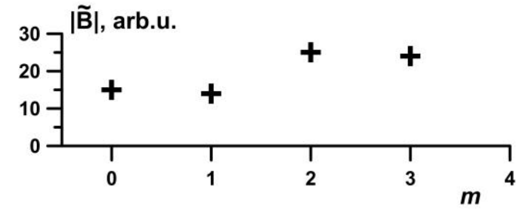

Fig. 2. The amplitude of fluctuations of the magnetic field near the plasma column boundary (r = 8.4 cm) depending on the poloidal wavelength m in the frequency band 5.9… 7.2 kHz

Maximum energy of magnetic field of plasma fluctuations is focused on low frequencies (Fig. 3). Here, $B_\Sigma^2 = \sum_{m=0}^{3} B_m^2$.

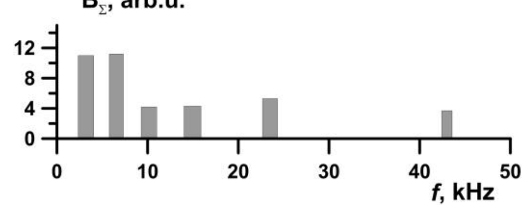

Fig. 3. The maximum energy of magnetic field fluctuations in different frequency ranges

Fig. 4 contains temporal behavior of fluctuations in one of the frequency ranges 5.9…7.2 kHz delivered to plasma boundary (r=8.4 cm) for various values of m. For m=0 the value is $\tilde{B}(t)$, and for other values of m the $|\tilde{B}(t)|$ value is given. From this figure it is clear that antinodes of fluctuations for all values of m are approximately in one and the same time range, however, the collision phases do not always match. Similar situation is observed for all frequency ranges.

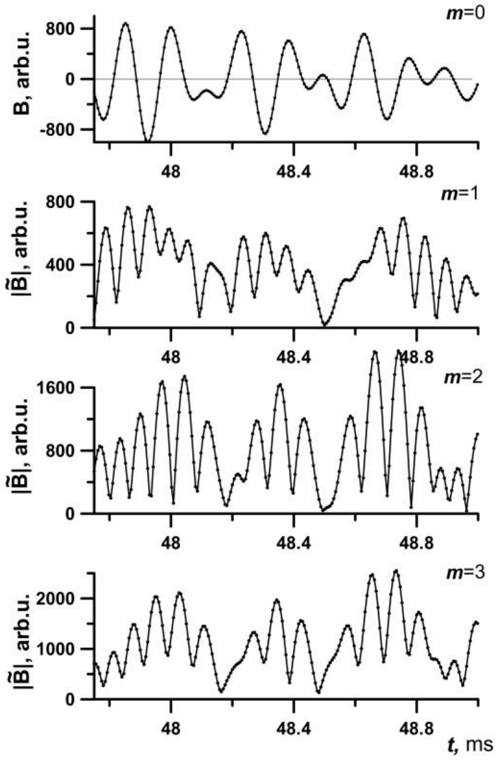

Fig. 4. The temporal behavior of magnetic field fluctuations recalculated for the plasma boundary in the frequency range 5.9 ... 7.2 kHz for different values of the wave number m. For m = 0, the current value of fluctuations is given, and for m = 1, 2, 3, the modulus of this value is presented

Two types of collisions are observed during quasi-stationary stage as well as during the dynamic stage of discharge (stage of discharge with increase of current and plasma energy content). “Standing” fluctuations, plasma current fluctuations, spatial structure do not change their azimuth, only amplitude changes. And collisions generated by “rotation” structure. In this case the amplitude of the structure with set wave number changes rather slowly, and the structure rotates with certain frequency. Typically, these types of fluctuations are observed at the same time, but purely “rotation” structure is almost never observed. Fig. 5 has an example of such fluctuations for m=2 and frequency range 2.5…3.9 kHz. Fig. 5,a demonstrates the behavior of current phase of the structure during the time and amplitude module. It is clear that up to the moment of time 67.75 ms of the structure with m=2, mainly, stands still (phase changes for π due to change of symbol during fluctuations) and fluctuates with frequency about 3.6 kHz. Starting from the time 67.95 ms the amplitude

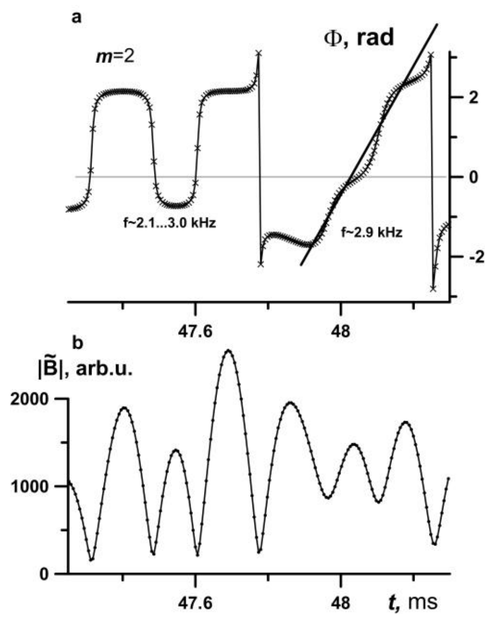

Fig. 5. The temporal behavior of the current phase Φ and the modulus of $|\tilde{B}(t)|$

of “standing still” structure decreases (see Fig. 5,b). Rotation of this structure occurs with average frequency 2.6 kHz (see Fig. 5,a). This fig. contains both “standing” and “rotation” structures. Due to this, one can see that “standing” structure transfers from one position to another by rotating at low amplitude of collisions. Fig. 6 shows the segment of Fig. 5 in bigger scale.

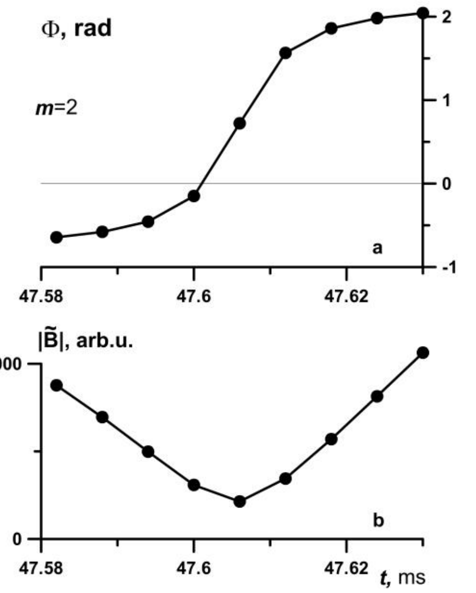

Fig. 6. The current phase and oscillation fluctuation modulus for m = 2 in the frequency range 2.5 ... 3.9 kHz in the time range 47.58 ... 47.64 ms

The work [1] demonstrated that during the dynamic stage of discharge there is a rotation of mainly of structure with m=2 in the direction of diamagnetic drift of electrons. Quai-stationary stage has rotation in both directions (electron and ion drifts) almost for all values of poloidal wave numbers (m=1, 2, 3). Fig. 7 provides

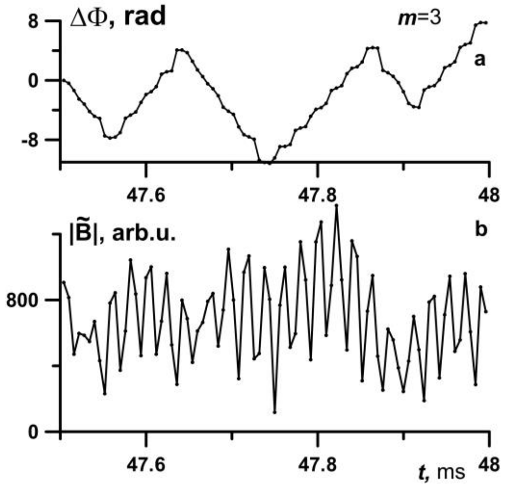

Fig. 7. Cumulative phase shift for a structure with m = 3 in the frequency range of 20 ... 27 kHz

time behavior of structure phase with m=3 in the frequency range 20…27 kHz (see Fig. 7,a) and module of fluctuation amplitudes) Fig. 7,b. It is clear that the investigated structure rotates alternatively with frequency 21 and 27 kHz; and "standing" structure fluctuates within the frequency range 20…25 kHz.

CONCLUSIONS

1. Signals from probes during quasi-stationary stage do not have stationary character and their processing requires the use of procedures described in the work [1] (see Fig. 1).

2. Fluctuations are observed in frequency ranges 2.5…3.9, 5.9…7.2, 9.4…10.9, 14…15.9, 20…27, 39…47 kHz, which does not have principal difference from dynamic stage of discharge.

3. Poloidal structure of fluctuations has wave numbers m=0; 1; 2; 3. Since higher values of m are determined with a larger error, moreover, they are noticeably smaller in magnitude.

4. The largest in magnitude in all frequency ranges are fluctuations with m-2 and 3 (see Fig. 2).

5. Maximum energy of fluctuations of magnetic field at the boundary of plasma cord is focused on low frequencies 2.5…3.9 and 5.9…7.2 kHz (see Fig. 3).

6. There are two types of fluctuations: "standing" and "rotation" (see Fig. 5).

7. "Rotation" structure can rotate in the direction of both electron and ion diamagnetic drifts. Hence during the dynamic stage of discharge the rotation was observed mainly in the direction of electron diamagnetic drift except at very low frequencies.

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СТРУКТУРА МГД-ФЛУКТУАЦИЙ В ТОРСАТРОНЕ У-3М В КВАЗИСТАЦИОНАРНОЙ СТАДИИ РАЗРЯДА

В.К. Пашнев, Э.Л. Сороковой, А.А. Петрушеня, Ф.И. Ожерельев

Проведено изучение структуры МГД-флуктуаций в квазистационарном режиме слабостолкновительного разряда в торсатроне У-3М в диапазоне частот 0,5…70 кГц. Были обнаружены флуктуации магнитного поля в следующих диапазонах частот: 2,5…3,9; 5,9…7,2; 9,4…10,9; 14…15,9; 20…27; 39…47 кГц. Была получена полоидальная структура МГД-активности плазмы с волновыми числами m=0; 1; 2; 3, что позволило определить уровень флуктуаций магнитного поля внутри объема удержания. Показано также, что существуют стоячие и вращающиеся структуры. Вращающиеся структуры могут вращаться как в направлении ионного, так и электронного диамагнитного дрейфов.

СТРУКТУРА МГД-ФЛУКТУАЦІЙ В ТОРСАТРОНІ У-3М У КВАЗІСТАЦІОНАРНІЙ СТАДІЇ РОЗРЯДА

В.К. Пашнєв, Е.Л. Сороковий, А.А. Петрушеня, Ф.І. Ожерел'єв

Проведено вивчення структури МГД-флуктуацій в квазістаціонарному режимі розряда з малими частотами зіткнень у торсатроні У-3М у діапазоні частот 0,5...70 кГц. Були виявлені флуктуації магнітного поля в наступних діапазонах частот: 2,5…3,9; 5,9…7,2; 9,4…10,9; 14…15,9; 20…27; 39…47 кГц. Була отримана полоідальна структура МГД-активності плазми з хвильовими числами m = 0; 1; 2; 3, що дозволило визначити рівень флуктуацій магнітного поля всередині обсягу утримання. Показано також, що існують стоячі і обертові структури. Обертові структури можуть обертатися як у напрямку іонного, так і електронного діамагнітного дрейфів.