XIX International Conference on Phenomena in Ionized Gases

Contributed Papers

Monday 10th July 1989

FACULTY OF PHYSICS
UNIVERSITY OF BELGRADE

10-14 July 1989

MHD - INSTABILITY OF THE HOLLOW CYLINDRICAL PLASMA STREAM

A.A.Kabantsev and S.Yu.Taskaev

Siberian Division of the USSR Academy of Sciences, Institute of Nuclear Physics, Novosibirsk, USSR

Introduction

Plasma stream transport from the annular plasma gun into the axisymmetric trap by means of the non-uniform axial magnetic field has been studied. Filling of the inner hollow of the plasma stream was found in our previous experiments [1,2]. Considerable magnitude of plasma density oscillation responsible for this filling was noted too. It was shown, that this filling was happening in front of the trap mirror due to development of the some fast instability at the region B of bad curvature of magnetic lines (see Fig. 1).

The objective of this work is to determine the nature of this instability of the plasma stream.

Experimental setup

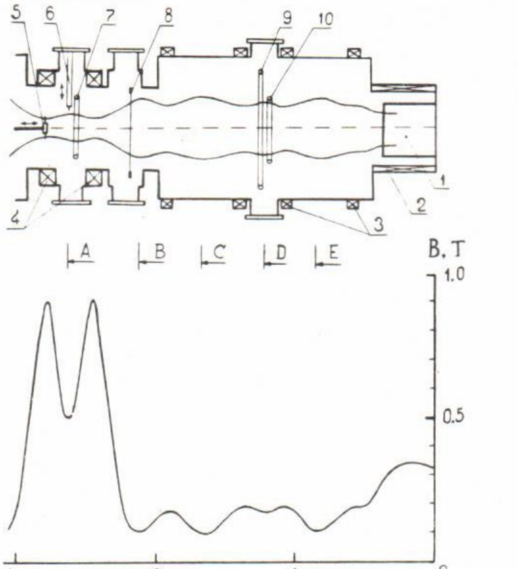


Fig. 1. Experimental setup and axial magnetic field profile: 1 - plasma gun; 2 - gun solenoid; 3 - transitional region coils; 4 - mirror coils; 5 - azimuthal probes; 6 - movable Langmuir probe, 7,8 - diamagnetic loops; 9,10 - Rogovski coils.

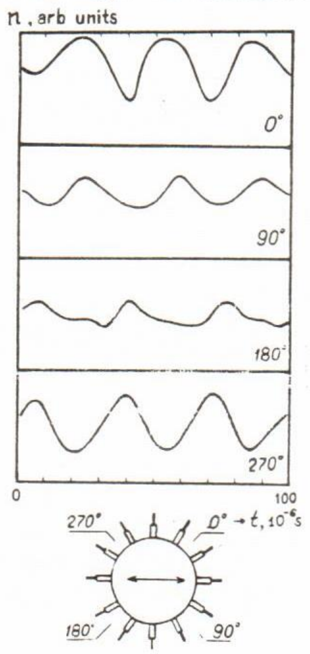
The experimental setup and axial magnetic field profile are shown in Fig. 1. A detailed description of the plasma gun used can be found in [3,4]. In accord with the annular shape of discharge channel the plasma stream radius at the source output is 6 cm and the thickness is 1 cm. Typical parameters in this initial region are plasma density $\sim 2\cdot10^{14}$ cm^{-3}, electron temperature $\sim$ 15 eV, ion temperature $\sim$ 45 eV and pulse duration $\sim$ 2 ms.

In order that to determine the azimuthal dependences of the plasma stream oscillations there is the system consisting of twelve Langmuir probes distributed uniformly along the azimuth. This system can be moved along the plasma stream axis too. Movable Langmuir probes are used to measure the radial profile of the plasma density $n(r)$, electron temperature $T_e(r)$ and floating potential $\varphi(r)$ in various sections. Dependence of oscillation phase from radius are controlled too. In addition, there are Rogovski coils and diamagnetic loops in some sections of the plasma stream.

It is necessary to note that transporting magnetic field has the following features. In regions of sections B, C and E (see Fig. 1) the plasma stream can be unstable against ballooning modes, and more unfavourable region from this point of view is the region B. The estimation of beta limits gives the following magnitudes beta (upper indexes correspond to regions): $\beta^B = 1,1\cdot10^{-3}$, $\beta^C = 1,6\cdot10^{-3}$, $\beta^E = 6\cdot10^{-3}$, where in plasma stream $\beta \sim 2\cdot10^{-2}$ (all values had been counted to the plasma gun output). The grossly stability of the plasma stream against flute/ interchange modes is due to the stabilizing influence of the cathode end of arc discharge. In particular, when the plasma gun is joined to trap without long transition region, then the flow of the plasma stream is stable and the filling of the its inner hollow is not observed.

Results

The analyses of experimental data obtained in this work show that there are the coherent low-frequency oscillations of plasma stream as rigid body (mode number $m = 1$) at frequency $f_0 \sim 30$ kHz (Fig. 2). The contribution of modes with high m number is negligible. This feature can be explained by the finite-Larmor-radius stabilization. The direction of oscillations which is determined by the some axial heterogenety of the magnetic field, weakly depends on ratio of magnetic fields in various regions and does not change along the axis of the plasma stream. Measurements with fixed probes located along the plasma column, but at the same azimuth revealed no axial phase shift for any mode of oscillations. This fact indicates of a flute type of oscillations.



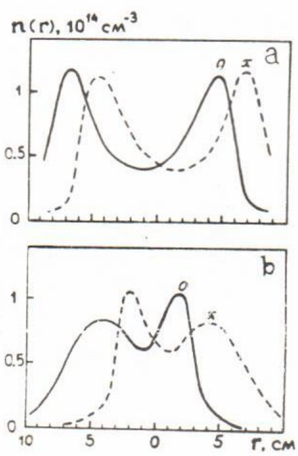


Fig. 2. Fig. 3.

Fig. 2. Plasma density oscillations measured by the azimuthal probes. The arrow shows the direction of oscillations.

Fig. 3. Radial plasma density profiles in opposite phases of oscillations: a) at region D ; b) at region A .

Additional effect associated with these periodical oscillations is destruction of the shape of the plasma stream cross section at the region B , whereas at the region D the initial shape of stream is conserving (Fig. 3,a). Since this distruction is carryed away along the stream by the plasma flow, then it can be observed at the region A (Fig. 3, b). These data enable one to conclude that at the region B the ballooning instability is developing. This instability does not observed in the first 300÷500 μs from beginning of the arc discharge, when the plasma density is small yet.

Owing to the development of these periodical ballooning modes there are separation from the plasma stream some "tongues" of plasma, which get on the walls of the vacuum chamber. This is confirmed by the tracks of arcs on the walls and by the quick decreasing of the electron temperature T_e on the unstable side of the plasma stream (on stable side $T_e \sim 15$ eV, on unstable side $T_e < 7$ eV).

The magnitudes of measured by Rogovski coils longitudinal currents of the plasma stream driven by arc discharge in the plasma gun depend essentially on the ratio of the diameter of the Rogovski coil to the one of the plasma stream. When the longitudinal electron current inside the plasma stream decreases with distance from the plasma source from $2 \cdot 10^3$ A at region D to $1,6 \cdot 10^3$ A at region A , then the total longitudinal current increses from 200 A at region D to 600 A at region A . If the flow of the plasma stream would be stable, then the total current must be equal zero, but the development of the ballooning modes leads to the loss of the some part of reverse current on the outer boundary of the plasma stream, that explains the observed dependences of longitudinal currents.

Conclusion

It is experimentally found the flow of the plasma stream, stabilized against flute /interchange modes by the stabilizing influence of the cathode end of arc discharge, is unstable against ballooning modes at region of bad curvature of the magnetic lines. The development of this instability lead to filling of the inner hollow and to destruction of the outer boundary of the plasma stream with corresponding loss of longitudinal current. The method of suppression these ballooning modes is given in [5].

[1] Ivanov A.A., Kabantsev A.A., et al. Preprint N 86-77, INP, Novosibirsk, 1986.
[2] Kabantsev A.A. In: XVIII ICPIG, Contr. Papers, v.2, p.430. Swansea, 1987.
[3] Dimov G.I., Ivanov A.A., Roslyakov G.V. Fiz. Plazmy, 1982, v.8, p.970.
[4] Ivanov A.A. Proc. Course on Mirror Based and Field Reversed Approaches to Magnet. Fusion, Varenna, 1983, p.279.
[5] Kabantsev A.A., Taskaev S.Yu. 1989, XIX ICPIG, Belgrade, Contributed papers.