Effect of ECR heating on the MHD activity of the plasma in the T-10 tokamak

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Experiments in the T-10 fusion research device reveal that ECR heating affects the behavior of the $m/n = 2/1$ MHD mode near the $q = 2$ resonant surface. The plasma heating outside (inside) the $q = 2$ surface is shown to stabilize (destabilize) the (2/1) mode.

Glasser *et al.*[1] have calculated the current profiles in tokamaks for which the discharge is MHD-stable according to the linear theory. Their results were subsequently confirmed by calculations based on the nonlinear theory,[2] which show that the

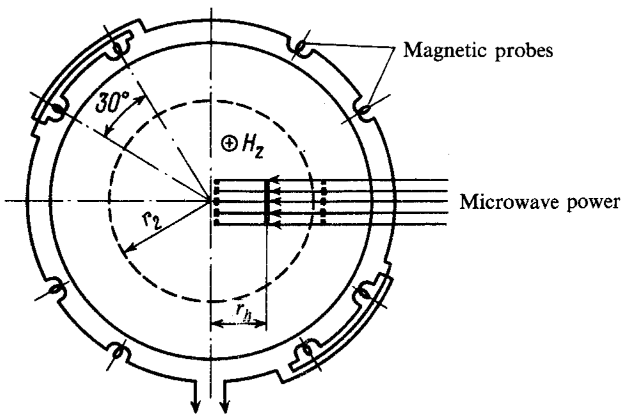

FIG. 1.

$m/n = (2/1)$ and $(3/2)$ MHD modes can be suppressed by raising the temperature (and therefore the current density) outside the $q = 2$ resonant surface. Finally, Chan and Guest[3] carried out calculations on the effect of plasma heating on the electron cyclotron resonance (ECR). It follows from their results that the absorption of a power ~ 1 W/cm^3 near the $q = 2$ surface suppresses the (2/1) and (3/2) modes for tens of milliseconds.

An ambitious program of research on ECR plasma heating is being carried out in the T-10 tokamak.[4] In particular, a series of experiments has been carried out to determine how this heating affects the intensity of the (2/1) mode when heating occurs near the $q = 2$ resonant surface. The position of the heating radius r_h was set by the strength of toroidal magnetic field H_z, which was varied from 30.4 to 34.0 kOe in these experiments; this field interval corresponded to a displacement of the ECR from 2 to 21 cm outward from the geometric axis of the minor cross section of the torus (Fig. 1). A power of 650 kW was injected at a wavelength of 3.6 mm; the power density was about 2 W/cm^3, and the pulse length was 0.1 s. The radius of the $q = 2$ resonant surface which was calculated from x-ray measurements of the temperature and effective charge, was found to be 18 cm at $H_z = 34$ kOe. The (2/1) mode was detected by a system of magnetic probes positioned and connected as shown in Fig. 1. The measurements were carried out in the following ranges of T-10 operating conditions: currents 225–280 kA, magnetic fields of 30.4–34.0 kOe, densities of $(3–4.5)\times 10^{13}$ cm^{-3}, a radius of 34.5 or 28 cm for the movable limiter, and a safety factor of 3.2–4.7 at the limiter.

Figure 2a shows an oscilloscope trace of the envelope of the signal corresponding to the (2/1) mode in a regime with ECR heating inside the $q = 2$ surface; Fig. 2b shows a corresponding trace for heating outside the $q = 2$ surface ($r_h = 21$ cm). We see that in the first case the heating has a destabilizing effect on the (2/1) mode (it increases the signal by a factor of two), while in the second case it has a stabilizing effect (it reduces the signal by about an order of magnitude). The signal level is proportional to the product of the amplitude and frequency of the emf induced in the coil. Measurements

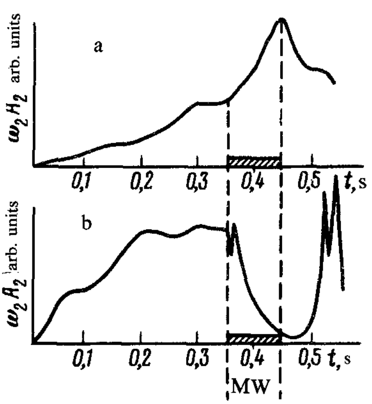

FIG. 2.

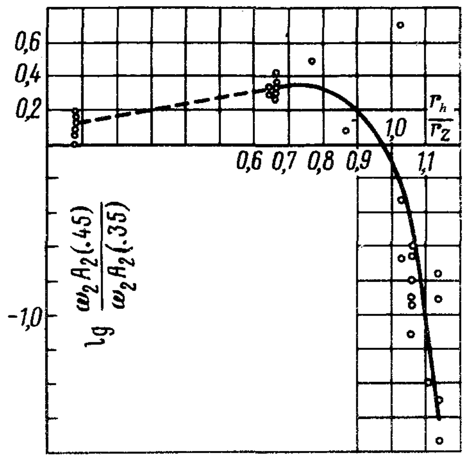

FIG. 3.

revealed that the frequency of this mode varies in phase with the MHD signal during the ECR heating. An important point is that in the case of "internal" heating (Fig. 2a) the increase in the signal level is due primarily to an increase in the frequency, while in the case of "external" heating (Fig. 2b) the decrease in the signal is due primarily to a decrease in the amplitude.

Figure 3 shows experimental data from the set of measurements. Plotted along the abscissa is the ratio of the ECR radius r_h to the radius (r_2) of the $q = 2$ surface, while the quantity plotted along the ordinate is the logarithm of the ratio of the signal of the (2/1) mode at the end of the heating (at 0.45 s) to the level of this signal before the heating (at 0.35 s).

It can be concluded from these results that the argument that the (2/1) MHD instability can be stopped and even suppressed by increasing the electron temperature outside the $q = 2$ rational surface is fundamentally correct. These results thus raise the hope that ECR heating can be used as a warning signal of impending instabilities leading to a major disruption. They also raise the hope that the working range of the safety factor at the limiter can be extended to $q < 2$.

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[4]Tenth European Conference on Controlled Fusion and Plasma Physics, Vol. 2, Moscow, 1981, p. 11.

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