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Magnetohydrodynamic instabilities in Iran-Tokamak 1(IR-T1)

HOJABRI Alireza[1,2] , GHORANNEVISS Mahhmod[2] and HAJAKBARI Fatemeh[1]

[1] *Physics group, Islamic Azad University, P.O.Box 31485-313, Karaj, Iran.*

[2] *Plasma physics Research Center, Islamic Azad University, P. O. Box 14665-678, Tehran, Iran.*

Abstract

In the present paper, an attempt is made to explain the behaviour of the magneto-hydro-dynamic (MHD) instabilities observed at low value of the edge safety factor on the basis of experimental results on the Iran Tokamak 1(IR-T1). A Hugill-diagram for IR-T1 and the boundaries of operating parameter space is shown. This work draws on previous studies carried out over a significant range of parameters, which showed that the MHD behaviour can be characterized by the single parameter q(a).

Introduction

The tearing mode instability and the associated magnetic islands can lead to a degradation of tokamak plasma performance and eventually to a disruption [1]. From the saturated width of the magnetic islands associated with the (m=2/n=1) tearing mode, the poloidal magnetic field fluctuations at the Mirnov coils are calculated and compared with the experimental results [2]. An important problem related to disruptions is the evolution of magnetic islands that may develop on the q=1, q=2, … surfaces [3]. When the island width becomes larger than the resistive layer of the tearing-mode theory, the problem becomes non-linear [4]. There was a clear correlation between particle confinement and MHD fluctuations. Higher densities resulted from puffing into discharges with low-level Mirnov oscillations and clear internal disruptions, as opposed to discharges with high-level oscillations and no (or very weak) internal disruptions. Furthermore, a moderate gas puffing early in the discharge frequently converted the MHD signature to that favorable for strong gas puffing. Such a technique was used to obtain higher densities. In the present paper, an attempt is made to explain the behaviour of the magneto-hydro-dynamic (MHD) instabilities observed at low value of the edge safety factor on the basis of experimental results on the Iran Tokamak 1(IR-T1). A Hugill diagram for IR-T1 and the boundaries of operating parameter space is shown. The start of MHD oscillation varies by changing plasma current, plasma horizental displacement and gas pressure.

EXPERIMENTAL SETUP

The IR-T1 is a conventional tokamak with aspect ratio R/a = 45 cm/12.5 cm, and a circular cross-section without a copper shell. It has no divertor but rather uses a material with a minor radius of 11.5 cm. The typical plasma parameters of IR-T1 operated in low-q are as follows: I_p=30-60kA, B_t=0.6-0.9T, n_e=(1.1-3.2)*10^{13}cm^{-3}, T_e=50-200eV and Z_{eff}=1-2.5. The main diagnostics used were a visible spectrometer and five-channel electron cyclotron emission (ECE) and electromagnetic measurement systems [5].

EXPERIMENTAL RESULTS AND DISCUSSION

A typical shot including a major disruption is illustrated in figure 1. In this shot, for which q(a) =2.4, the major disruption considered sets in at 23.7 ms. The main characteristics are: a major decrease in the plasma current after vertex close to 23.7 ms (figure 1(a)); several negative spikes in the loop-voltage signal(figure 1(b)); a displacement of the plasma column towards the inner part of the torus due to instability(figure 1(c)); edge losses through the interaction of the plasma column with the limiter, manifesting itself in pulsed increases in the H_α (λ=6563 ^{o}A, 3-2) signal (figure 1(d)) and OII impurity signal (figure 1(e)) and a high level of magnetic turbulence corresponding to relatively large poloidal-field fluctuations at the location of the Mirnov coil(figure 1(f)).

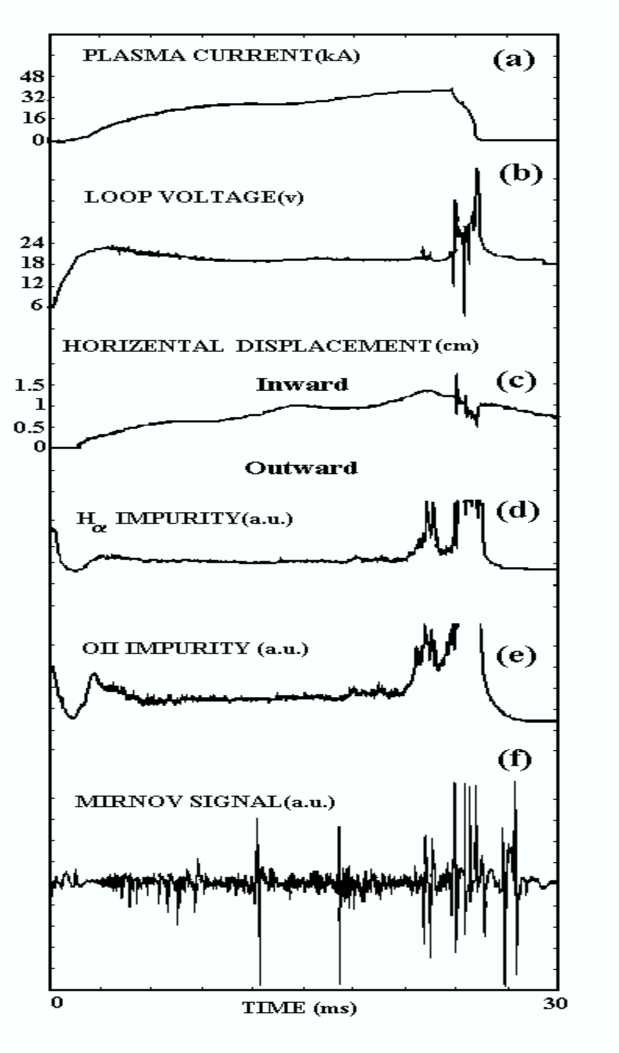

Figure 1. Time history of the main parameters in the IR-T1 tokamak.

The classical description of the scaling for the density limit is well known as the Murakami-Hugill limit [6]. The value of the density limit is found to vary from machine to machine [7]. The result is shown in figure 2 in Hugill-diagram. Hugill diagram showing the boundaries of the IR-T1 operating parameter space. The region is bounded below by the high density limit at roughly D = 3.15 (where $D = qn_eR/B_T$), above by the high current limit at q = 2, and to the left by the low density locked mode limit. For low q, in a clean machine the low density limit is D = 0.4 [8]. This figure shows that major disruptions most likely occur in a fairly restricted region of the Hugill space, between curves A and B (which only delineate the experimental points).

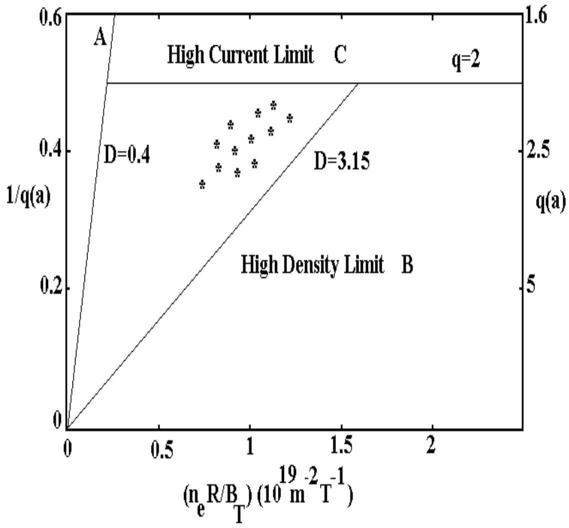

Figure 2. Hugill diagram showing the Boundaries of the IR-T1 operating parameter space.

The dependences of the energy Confinement time on the parameters q(a) and n_e were systematically investigated by: 1) fixing B_t and n_e and changing q(a), i.e. q(a)= 2.3 and 3; and 2) fixing B_t and q(a) and changing n_e, i.e. $n_e=1.1*10^{13}cm^{-3}$ and $3.2*10^{13}cm^{-3}$. The results are consistent with Alcator, Mirnov and DIVA scaling [9] in that the confinement time is almost proportional versus $q(a)^{0.5}n_e$. Figure 3 shows the energy confinement time to n_e and roughly proportional to $q(a)^{0.5}$. The experimental results are agreement with this scaling.

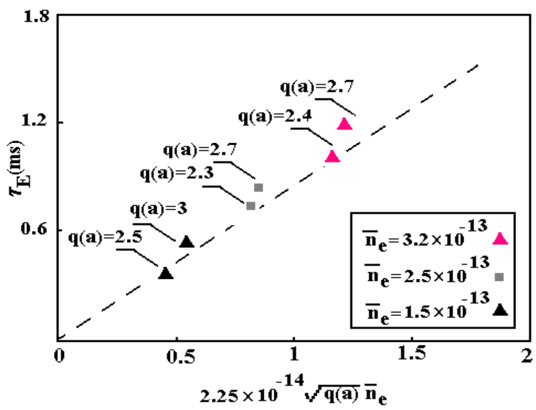

Figure .3 Energy confinement time versus $q(a)^{0.5}n_{e.}$

CONCLUSION

In this work we have described detailed measurements of disrupting hydrogen plasmas. The major disruption in IR-T1 is preceded by the growth of a precursor mode oscillation. A Hugill diagram for IR-T1 and the boundaries of operating parameter space is shown and the energy confinement time in various experimental conditions is obtained.

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