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MHD Activity and Disruption in Low-q(a) in Iran Tokamak 1 (IR-T1)

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Abstract

In the present paper, an attempt is made to explain the behavior of the magneto-hydro-dynamic (MHD) instabilities observed at low values of the edge safety factor q(a) on the basis of the experimental results on the Iran Tokamak1 (IR-T1). A Hugill diagram for IR-T1 is shown. In addition to the well known low q and high-density limits. It is found that the disruption activity occurs when value of the safety factor in the plasma edge is less than 2.7.

Keywords:

IR-T1 tokamak, low-edge safety factor, disruption, density limit, Hugill diagram

1. Introduction

Tearing modes are known to play an important role in confinement degradation and disruption in tokamaks [1]. They are resistive instabilities driven by the free energy contained in the poloidal magnetic field. Due to their resonant character, they are localized around flux surfaces and change the topology of the magnetic flux distribution through the formation of magnetic islands. At present, there are several distinct MHD models of tokamak disruptions, a) the interaction of a single magnetic island of helicity (m=2)/(n=1) with the limiter or cold-gas region ruins the energy confinement [2], b) the disruptions are believed to be triggered by the nonlinear coupling of modes of different helicities. In cases where both the (m=2)/(n=1) and the (m=3)/(n=2) modes are unstable, a broad spectrum of waves is excited which destroy magnetic surfaces and therefore strongly enhance cross-field thermal collapse in the region of the stochastic magnetic field [3]. c) A nonlinear interaction between the (m=1)/(n=1) and (m=2)/(n=1) modes, taking place through the intermediary of the current profile, was proposed [4]. Understanding in detail the various mechanisms that can lead to disruption is important for achieving tokamak confinement, and especially so with a view to suppressing disruptions [5]. In this paper, we present density behavior in IR-T1 tokamak, and systemically examine ohmic data during different operating conditions.

2. Experimental Results and Discussion

The IR-T1 is a conventional tokamak with a major and minor radii of 45 cm and 12.5 cm, respectively, and a circular cross section without a copper shell and divertor and using a material limiter of minor radius 11.5 cm. A typical shot including a major disruption is illustrated in Fig. 1. In this shot, where toroidal field 0.6 tesla and mean electron density 1.2×10^{13} cm^{-3} for which q(a)=2.3, the relevant major disruption sets in at 12.2 ms. The main characteristics are: 1) the major decrease of the plasma current after two small vertex close to 12.2 ms and 12.8 ms (Fig. 1a), 2) negative spikes in the loop voltage signal corresponding to plasma current

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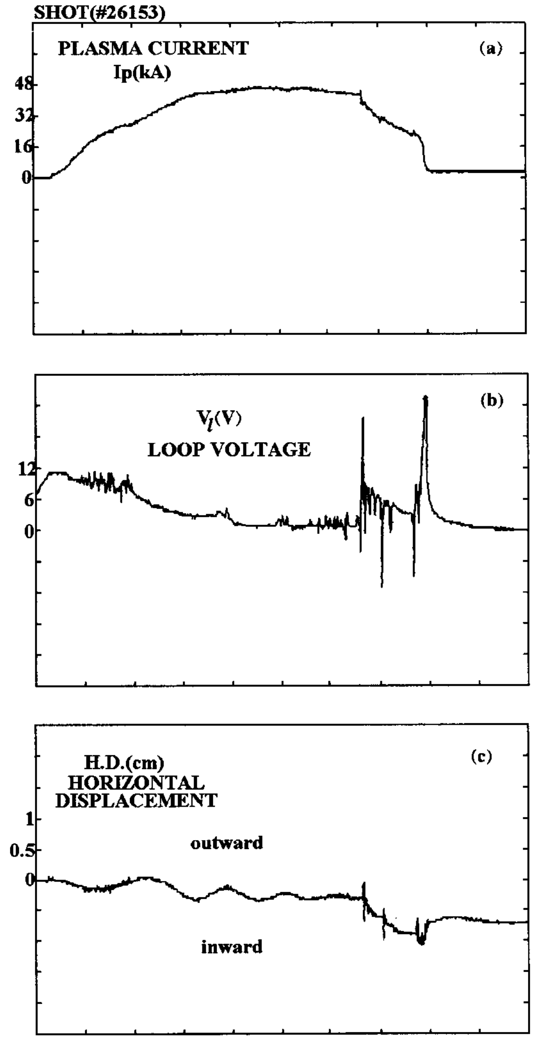
vertexes (Fig. 1b), 3) a displacement of the plasma column towards the inner part of the torus due to instability (Fig. 1c), 4) decrease of the electron temperature is shown by a fast decrease in the electron cyclotron emission (ECE) of the plasma (Fig. 1d) and 5) (m=2)/(n=1) mode has a relatively low amplitude up to ten milliseconds before the disruption (Fig. 1e). In the first phase of a major disruption differed from a minor disruption by a stronger decrease in the electron temperature at the center of plasma (Fig. 1e). Before disruption, the ECE radiation from the plasma center presents sawtooth like oscillations, which affect the central part of the discharge and level the electron temperature. The ECE intensity decays with the development of the (m=2)/(n=1) instability and precursors of disruptive energy loss in the central part of the plasma appear. 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 [7-9]. The result is shown in Fig. 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 $D = 0.4$ [10]. 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). Low q ($2<q<3$) discharges were obtained in the IR-T1 tokamak. It is found that the



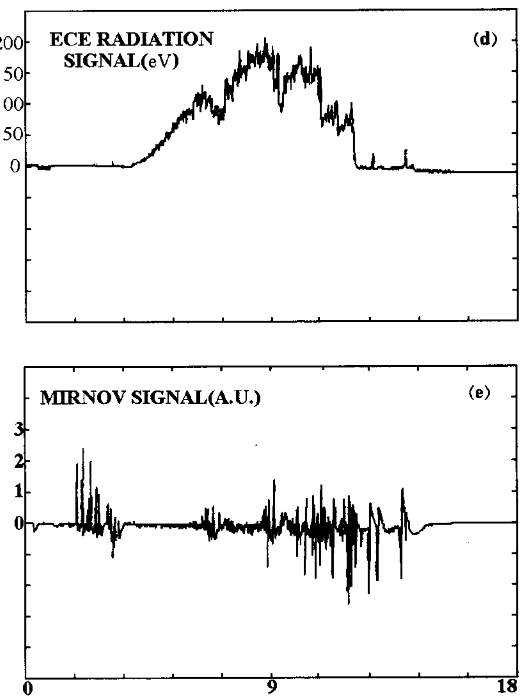


Fig. 1 Time behavior of principal parameters during the major disruption event on the IR-T1 tokamak; (a) plasma current (kA), (b) loop voltage (volt), (c) horizontal displacement signal (cm), (d) ECE signal (eV). (e) Mirnov coil signal (arb. units). The disruptive instability appears close to 12.2 ms.

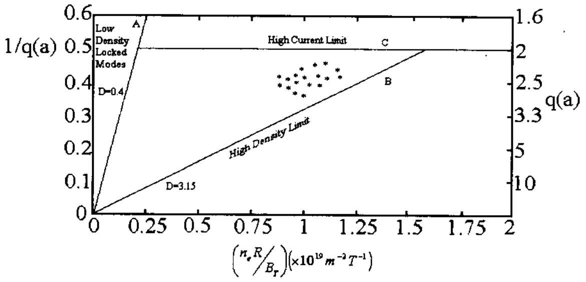


Fig. 2 Hugill diagram showing the boundaries of the IR-T1 operating parameter space.

disruption activity occurs, when value of the safety factor in plasma edge is less than 2.7. It was necessary, for a tokamak operating at these q values without a conductive shell and using a material limiter, to make a careful adjustment of the plasma parameters and have an appropriate ramp-up rate of plasma current in the startup phase and low Z_{eff}.

3. Conclusion

In this work we have described detailed measurements of disrupting hydrogen plasmas in the ohmic-heating regime. The major disruption in IR-T1 is preceded by the growth of a precursor mode oscillation. It is found that the disruption activity occurs, when value of the safety factor in plasma edge is less than 2.7. In this regime, there are the sequence of the sawtooth like oscillations in ECE radiation and a (m=2)/(n=1) tearing mode.

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