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Il Nuovo Cimento D
July 1996, Volume 18, Issue 7, pp 807-821

Observation of disruptions in tokamak plasma under the influence of resonant helical magnetic fields

Summary

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IL NUOVO CIMENTO VOL. 18 D, N. 7 Luglio 1996

Observation of disruptions in tokamak plasma under the influence of resonant helical magnetic fields (*)

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(ricevuto il 19 Giugno 1995; approvato il 20 Febbraio 1996)

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PACS 52.30 – Plasma flow; magnetohydrodynamics.
PACS 52.70 – Plasma diagnostic techniques and instrumentation.
PACS 02.30.Nw – Fourier analysis.

1. – Introduction

The harmful consequences of disruptions in tokamaks are already well known. Depending on their strength, they significantly deteriorate the plasma confinement (minor disruptions) and can even lead to its complete loss (major disruptions). Furthermore, the rapid plasma current decay that follows a major disruption can cause severe stress on the electric-mechanic components of the tokamak. However, despite the intense study that has already been performed during the last decades [1-10], the causes associated to the occurrence of the disruptive instabilities are not yet well understood and, presently, this is still one of the main obstacles to the controlled-thermonuclear-fusion research. Accordingly, scaling analysis involving

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different tokamaks as the COMPASS, DIII-D, and JET, indicates that the solution to this problem will be of great importance to the next generation of even larger tokamaks [11].

The disruptive instabilities are usually preceded by a fast amplitude growth of MHD modes and, in particular, the major disruptions are commonly observed to be preceded by a sequence of minor disruptions. The main characteristics of major disruptions are: fast negative spike in the loop voltage signal, rapid loss of confined energy and sudden expansion of the plasma minor radius, with a diminution of the major radius.

Since the major disruptions lead to the complete destruction of the plasma confinement, they are the ones that had deserved more attention. Thus, the knowledge of the processes through which a major disruption is created has been the object of great concern and was specifically considered in several works in the literature; many of them present strong evidences that the $m/n = 2/1$ amplitude increase is mainly responsible for triggering this instability. In this context, the interaction of the $m/n = 2/1$ islands with the limiter [12], the coupling between the $m/n = 2/1$ and $m/n = 1/1$ modes [10, 13], and the destabilization of odd m-value modes, such as $m/n = 3/2$, by the growing $m/n = 2/1$ islands [7, 14], were some of the proposed mechanisms to explain the development of major disruptions.

However, despite all the experimental evidences and theoretical work that has been performed, several aspects concerning the major disruptions are still the object of strong controversy. The role played by impurities (Marfes, the rate of radiated power in relation to the input power, the influence of low-Z materials first wall coatings, etc.) and the absence of any precursors to some disruptions are, for example, features that still need further clarification [15-18].

In relation to mechanisms of controlling and possibly suppressing the onset of major disruptions, different processes and systems have already been proposed [19]. Among these, the use of resonant helical windings (r.h.w.) has produced interesting results. The first pioneer studies, showing how disruptive instabilities are affected by resonant helical magnetic fields (r.h.f.), were carried on the Pulsator tokamak discharges, which showed that the occurrence of a major disruption could be either delayed or activated, in response to a weak externally imposed magnetic perturbation created by an $m = 2/n = 1$ r.h.w. [20, 21]. After this work, other investigations involving the application of resonant helical magnetic fields in different tokamaks have been performed, extending the previous results to different discharges conditions and other perturbing helical modes [5, 6, 22-26]. Basically, these experiences showed that the application of r.h.f. could strongly attenuate the Mirnov oscillations amplitude. Therefore, this would mean that the intrinsic nature and the way the disruptive instabilities are triggered could then be investigated with this winding.

More recently, experimental data, supported by theoretical results [27-31], showed that locked modes could be created as a result of naturally existing (or artificially created) error fields. As a rule, when a mode locking occurs, the MHD perturbation amplitude is observed to decrease drastically, as a consequence of the fact that the magnetic islands stop rotating. This would mean that the attenuation of MHD activity, commonly observed during the application of resonant helical magnetic fields, could not be interpreted as a diminution in size of the magnetic islands but, rather, only as an indication that the magnetic islands are slowing down.

It should be noted, however, that whenever a locked mode occurs, the plasma has a strong probability to disrupt. High-current disruptive pulses in JET, for example,

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Journal
Il Nuovo Cimento D
Volume 18, Issue 7 , pp 807-821
Cover Date
1996-07-01
DOI
10.1007/BF02457314
Print ISSN
0392-6737
Publisher
Kluwer Academic Publishers

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