RESISTIVE MHD-MODES, TOROIDAL PLASMA ROTATION AND DISRUPTIONS

G. Waidmann, P.C. de Vries*, R. Jaspers* and A. Krämer-Flecken

Institut für Plasmaphysik, Forschungszentrum Jülich GmbH
Trilateral Euregio Cluster, Association EURATOM-FZJ
D-52425 Jülich, Germany

**FOM Instituut voor Plasmafysica 'Rijnhuizen', Trilateral Euroregio Cluster,*
Association EURATOM-FOM, 3430 Nieuwegein, The Netherlands

Abstract

In a systematic continuation of previous studies, resistive MHD-instabilities were experimentally investigated in TEXTOR-94 under various operational conditions. Their onset and growth limits the plasma energy content already far below the Troyon β-limit. For detailed studies, magnetic islands were generated on purpose in low collisionality plasmas ($\bar{n}_e = 1 \times 10^{19}\ m^{-3}$) . Their growth and decay is strongly influenced by details of the toroidal plasma rotation profile. Making use of the flexibilitv in programming co-plus counter direction neutral particle injection beams, various rotation profiles could be produced. Mode coupling between m/n = 2/1 and m/n = 1/1 occurred when in rigidly rotating plasmas a low rotation velocity was produced. A change in the rotation profile during a discharge was achieved by turning off one of the two beams. The resulting stronger velocity shear in the rotation profile led then to a quench of the islands. A threatening plasma disruption was avoided.

1. Introduction

Non-ideal MHD instabilities are observed in TEXTOR plasmas under various operational conditions. They limit the stored plasma energy content far below the Troyon β-limit. They are frequently encountered in low collisionality plasmas. A typical example for its appearance is the early phase of plasma built-up at the beginning of the current plateau. Prior to an Ohmic density limit disruption these instabilities can be found. In counter beam heated plasmas a central density peaking was observed. It is followed by tearing mode destabilization and a strong loss of plasma energy. In plasmas with heavy impurity accumulation in the central part, resistive instabilities are observed after central q-profile lift-up. These observations are reported from TEXTOR [l-3], COMPASS-D [4], D-III D [5] and ASDESX UPGRADE [6]. In TEXTOR, the intention to avoid magnetic islands or to stop its growth was systematically pursued. Making use of programmable co- and counter neutral beams, different toroidal plasma rotation scenarios could be set-up. This allowed us to study the effect of differential, toroidal plasma rotation on the evolution of resistive MHD-modes.

2. Tearing Modes in TEXTOR Plasmas

An example for the appearance of tearing modes in TEXTOR is shown in Fig. 1. The electron temperature behaviour from 2 opposite positions of the $T_e(r)$-profile is shown for the Ohmic phase and later for times t > 1.0 sec for the plasma with neutral beam heating. The islands of

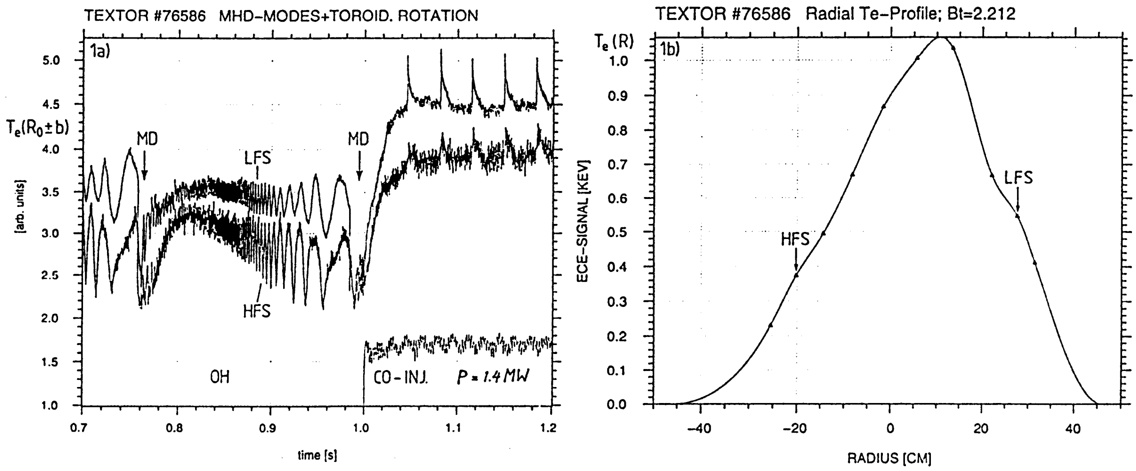

Fig. 1. a) ECE-signals from 2 positions of T_e-profile indicating m = 2 activity.
b) Arrows mark the radial position of the T_e-oscillations.

an m/n = 2/l mode modulate in phase, sinusoidally the ECE-signals received from LFS and HFS. Two minor disruptions are encountered after slowing down of the mode rotation frequency. The onset of a neutral beam injection in co-direction changes the situation drastically. The T_e-oscillations disappear and the familiar sawtooth activity reappears. A threatening major disruption is avoided here. Some details about this critical situation are found in the contour plots of electron temperature and electron density (Fig. 2). The m = 2 islands are visible on LFS and HFS. At the time t = 0.985 sec the m = 2-islands suddenly expand into the central q = 1 plasma region. This leads to the second minor disruption. At time t = 1.0 sec neutral beam injection begins to heat and induces a toroidal plasma rotation. The m = 2 mode is suppressed now; instead a sawtoothing discharge type is generated. The degraded energy confinement time is strongly improved by the suppression of tearing modes (E_{DIA}^{OH} = 16 kJ; E_{DIA}^{NBI} = 67 kJ).

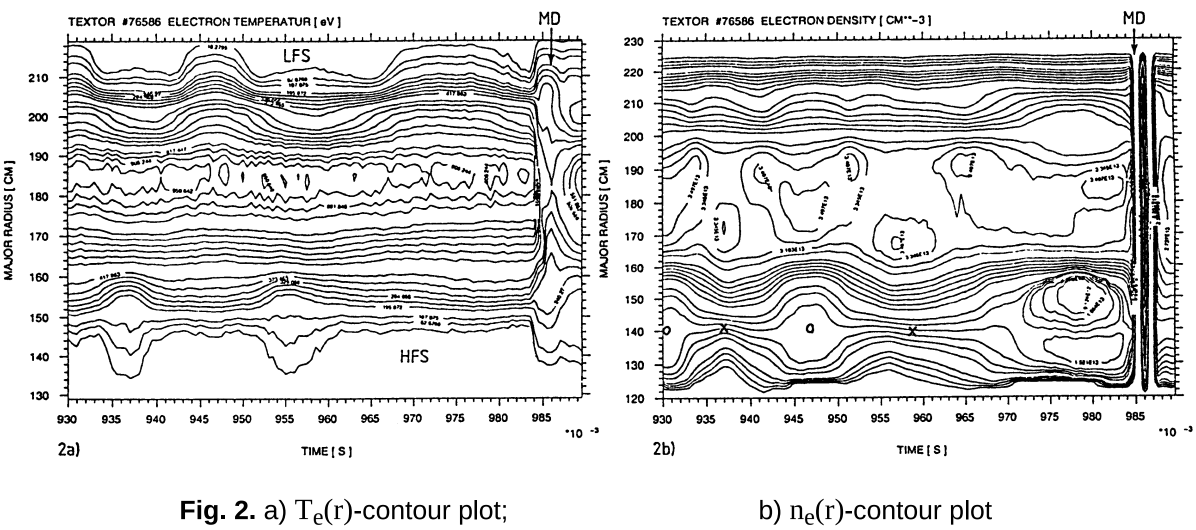

Fig. 2. a) T_e(r)-contour plot; b) n_e(r)-contour plot
T_e and n_e were measured at different toroidal positions on the vessel.
M.D. = minor disruption

3. Toroidal Plasma Rotation and MHD-Activity

The toroidal plasma rotation interacts with the evolution of resistive MHD-modes. The details of the rotation profile decide on the outcome of the interaction. A charge exchange recombination spectroscopy (CXRS) was used to evaluate the very different profiles which can be generated by means of co- plus counter neutral beam injection. Fig. 3 shows toroidal rotation profiles for the beam heated plasma of Fig. 1. With co-injection alone a strong radial gradient of toroidal velocity is found. A typical value of the ratio $\omega_{rot}/\omega_A = 0.024$ was calculated for the plasma center. The m = 2 islands are extinguished.

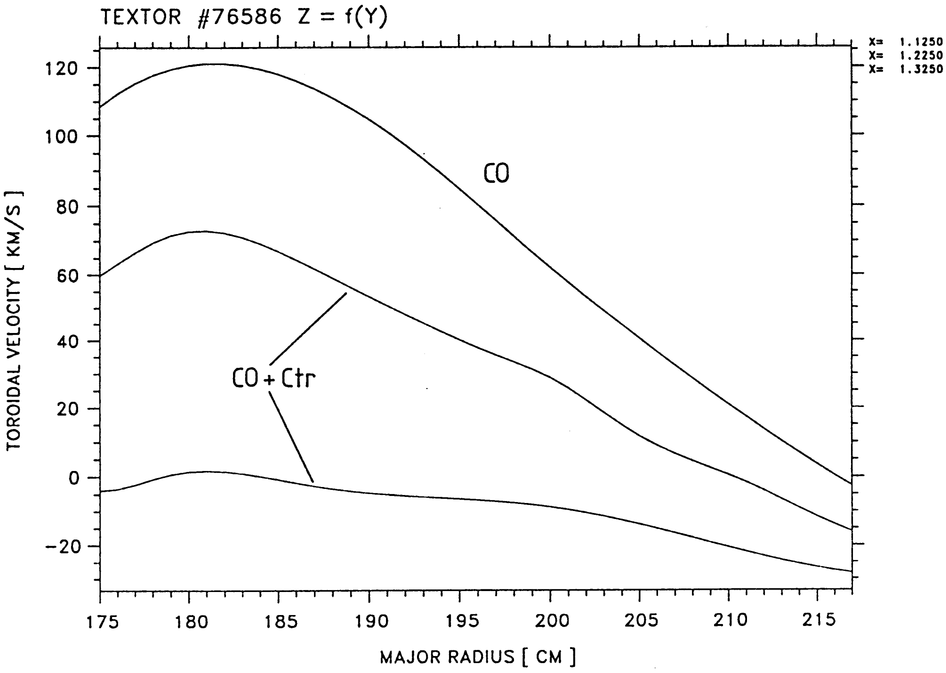

Fig. 3. Toroidal rotation profiles for CO and CO + Ctr beam injection. Differential rotation nearly disappeared in the lowest curve.

The onset of a delayed counter beam injection reduces this velocity down to the stop of rotation. Fig. 4 shows a situation where the turn-on of a second, but counter beam slows down the toroidal velocity and even inverts its direction. Up to the q = 2 surface a flat radial profile was found now. The rotation approaches the case of a rigidly rotating plasma body over a part of the radius. Now the m = 2-mode develops and couples with the inner m = 1-mode. A universal mode with a strongly modulated T_e- and n_e-profile is encountered. A major plasma disruption occurs at the time t = 2.2 sec. The turn-off of the second beam during MHD activity can bring back the proper, sheared velocity profile without disruption later on. Choosing the right profile, the growth of the modes can be limited and a long lasting m = 2-activity may be obtained (t > 1 sec) without disruption. Here the mode locking process is prevented by forced rotation.

The suppression of magnetic islands by plasma rotation was predicted by Persson [7] based on numerical computations. A similar result was obtained by Fitzpatrick et al. [8]. The exact mode behaviour depends then on details of the plasma flow.

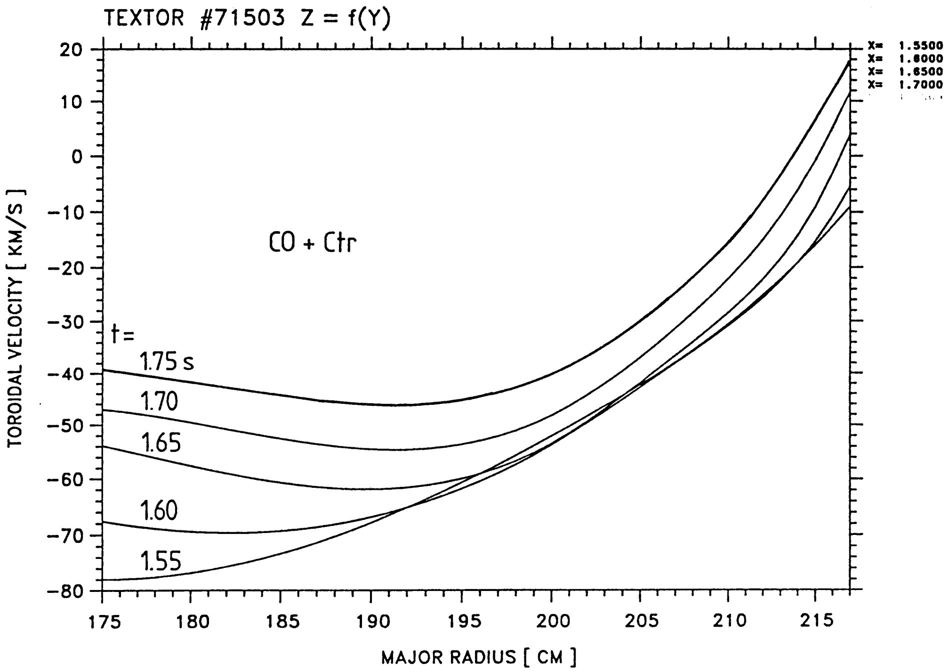

Fig. 4. Toroidal plasma rotation profiles which support tearing mode development.

4. Summary

Resistive MHD instabilities modify visibly the tokamak plasma profiles and deteriorate the energy confinement. The mode m = 2 and m = 1 couple with each other and form a global mode. The locking of this new mode leads often to plasma disruption. A differential, toroidal plasma rotation influences the mode evolution. The mode locking can be prevented, mode coupling can be broken up. The mode m/n = 2/l can be suppressed and a threatening plasma disruption can be avoided. A well timed start of the neutral beam injection provides a useful, sheared plasma rotation and suppresses the dangerous m/n = 2/l tearing mode.

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