GA–A26046

PLASMA PERFORMANCE IN DIII-D ELM-SUPPRESSED RMP H-MODES WITH ITER SIMILAR SHAPES

by

T.E. EVANS, M.E. FENSTERMACHER, M. JAKUBOWSKI, R.A. MOYER, T.H. OSBORNE, M.J. SCHAFFER, O. SCHMITZ, J.G. WATKINS, L. ZENG, L.R. BAYLOR, J.A. BOEDO, K.H. BURRELL, J.S. deGRASSIE, P. GOHIL, I. JOSEPH, C.J. LASNIER, A.W. LEONARD, C.C. PETTY, R.I. PINSKER, T.L. RHODES, P.B. SNYDER, E. UNTERBERG, and W.P. WEST

MAY 2008

GENERAL ATOMICS

DISCLAIMER

GA–A26046

PLASMA PERFORMANCE IN DIII-D ELM-SUPPRESSED RMP H-MODES WITH ITER SIMILAR SHAPES

by

T.E. EVANS, M.E. FENSTERMACHER,* M. JAKUBOWSKI,† R.A. MOYER,‡ T.H. OSBORNE, M.J. SCHAFFER, O. SCHMITZ,§ J.G. WATKINS,¶ L. ZENG,# L.R. BAYLOR,∞ J.A. BOEDO,‡ K.H. BURRELL, J.S. deGRASSIE, P. GOHIL, I. JOSEPH,‡ C.J. LASNIER,* A.W. LEONARD, C.C. PETTY, R.I. PINSKER, T.L. RHODES,# P.B. SNYDER, E. UNTERBERG,◊ and W.P. WEST

This is a preprint of a synopsis of a paper to be presented at the 22nd IAEA Fusion Energy Conference, October 13-18, 2008, in Geneva, Switzerland, and to be published in the *Proceedings.*

*Lawrence Livermore National Laboratory, Livermore, California.
†Max-Planck-Institut für Plasmaphysik, Greifswald, Germany.
‡University of California-San Diego, La Jolla, California.
§Forschungszentrum Jülich, Jülich, Germany.
¶Sandia National Laboratories, Albuquerque, New Mexico.
∞Oak Ridge National Laboratory, Oak Ridge, Tennessee.
#University of California-Los Angeles, Los Angeles, California.
◊Oak Ridge Institute for Science Education, Oak Ridge, Tennessee.

Work supported in part by
the U.S. Department of Energy
under DE-FC02-04ER54698, DE-AC52-07NA27344, DE-FG02-04ER54758, DE-AC04-94AL85000, DE-FG03-01ER54615, DE-AC05-00OR22725, and DE-AC05-76OR00033

GENERAL ATOMICS PROJECT 30200
MAY 2008

GENERAL ATOMICS

Plasma Performance in DIII-D ELM-Suppressed RMP H-modes with ITER Similar Shapes EX-D

T.E. Evans,[1] M.E. Fenstermacher,[2] M. Jakubowski,[3] R.A. Moyer,[4] T.H. Osborne,[1] M.J. Schaffer,[1] O. Schmitz,[5] J.G. Watkins,[6] L. Zeng,[7] L.R. Baylor,[8] J.A. Boedo,[4] K.H. Burrell,[1] J.S. deGrassie,[1] P. Gohil,[1] I. Joseph,[4] C.J. Lasnier,[2] A.W. Leonard,[1] C.C. Petty,[1] R.I. Pinsker,[1] T.L. Rhodes,[7] P.B. Snyder,[1] E. Unterberg,[9] and W.P. West[1]

[1]General Atomics, P.O. Box 85608, San Diego, California 92186-5608, USA
[2]Lawrence Livermore National Laboratory, Livermore, California 94550, USA
[3]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany
[4]University of California-San Diego, La Jolla, California 92093, USA
[5]Forschungszentrum Jülich, IEF-4 Euratom Association, Jülich, Germany
[6]Sandia National Laboratories, Albuquerque, New Mexico 94551, USA
[7]University of California, Los Angeles, California 90095, USA
[8]Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA
[9]Oak Ridge Institute for Science Education, Oak Ridge, Tennessee 37831, USA

Fast energy transients, incident on the DIII-D divertors due to Type-I edge localized modes (ELMs), have been eliminated using small dc currents in a simple set of internal non-axisymmetric coils that produce edge resonant magnetic perturbations (RMP) [1]. In plasmas with ITER similar shape (ISS) and electron pedestal collisionality, β_N and the H-mode quality factor are preserved at levels needed for ITER. The resonant window in edge safety factor (q_{95}) for ELM suppression can be expanded by a factor of 4 by increasing the RMP amplitude and mixing n=1 modes from a single-row external coil with n=3 modes from a two-row internal coil as shown in Fig. 1. For a fixed q_{95} the maximum ELM size is correlated with the width of the edge region over which the Chirikov parameter exceeds 1 as shown in Fig. 2. The effective particle confinement time and density are modestly reduced by the RMP. Density reductions ranging between 7% and 25% are observed depending on the coil currents used and target plasma conditions prior to the application of the RMP. The density can be transiently recovered by injecting a core-fueling pellet. Several small D_α transients typically follow a fueling pellet but in some cases a single transient, with a maximum size of less than 10% of a Type-I ELM, is observed. These cases approach the ITER requirement. At substantially higher coil current, ELM suppression is observed with an n=3 RMP from a single row of internal coils.

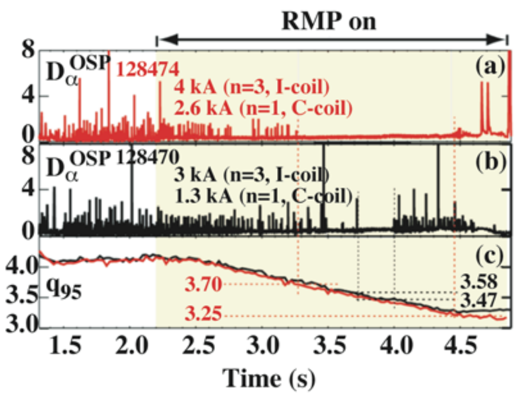

Fig. 1. Divertor, outer strike point (OSP), D_α showing ELM suppression in (a) between 3.3 s and 4.4 s and (b) between 3.7 s and 4.0 s. Safety factor at ψ_N = 0.95 (c) showing an increase in the ELM suppression resonant window by a factor of 4 with an increase in the I-coil and C-coil currents (i.e., δq_{95} = 0.11 in (b) and δq_{95} = 0.45 in (a).

In addition to the ELM suppression resonance centered at q_{95} = 3.5 shown in Fig. 1 we find isolated resonant windows exist at other q_{95} values with different RMP coil configurations. For example, when the I-coil is operated in an n=3 up-down asymmetric configuration rather than an up-down symmetric configuration a resonant window is found near q_{95} = 7.4. These results along with our ability to increase the q_{95} resonant window as shown in Fig. 1 indicate that properly designed RMP coils will be able to suppress ELMs over a wide range of operating scenarios in ITER. In addition, changing the discharge triangularity increases the size and location of the resonant ELM-suppression window in a way that is consistent with vacuum field line modeling expectations [1,2].

Vacuum field line modeling shows that there is a strong statistical correlation between a threshold value of the edge stochastic layer width and ELM suppression. In particular, when the Chirikov overlap parameter (σ_{Chir}) ≥ 1.0 over the interval 0.85 ≤ ψ_N ≤ 1.0 in discharges with stationary q_{95} inside a given resonant window ELM suppression is always observed (Fig. 2) [2]. This criterion has been a valuable guide for RMP coil design studies in various ITER operating scenarios. When *n*=3 RMP fields from the DIII-D internal coil (I-coil) are applied to plasmas with pre-existing *n*=1 field-error correction coil (C-coil) currents there is typically a reduction in the line-averaged and pedestal density even though q_{95} is outside the resonant ELM-suppression window. The transition from RMP ELMing to RMP ELM suppressed period has been observed without additional density pump-out. Measurements of the total pedestal pressure profile have shown that this transition involves a localized reduction in the total pressure gradient that occurs between 0.80 ≤ ψ_N ≤ 0.95.

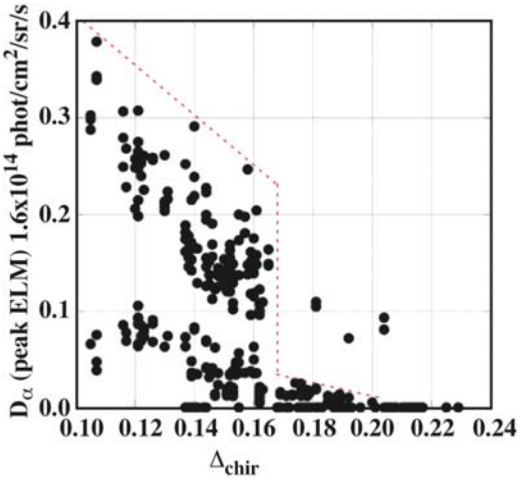

Fig. 2. ELM size (normalized D_α intensity) during *n*=3 RMP from both I-coils as a function of the width Δ_{chir} of the edge stochastic region (with σ_{chir}>1) showing good correlation between the maximum ELM size and Δ_{chir} below Δ_{chir} =0.165 and suppression of Type-I ELMs above this threshold value.

High-field side (HFS) D_2 fueling pellets have been used to verify that the effective particle confinement time (τ_p^*) is reduced from ~500 ms during an ELMing H-mode to ~250 ms during RMP ELM suppression. In addition, fast profile reflectometry measurements of the pedestal density profile show signatures of localized increase in the density transport near the top of the pedestal, at ψ_N = 0.95, early in the I-coil pulse when the density pump-out occurs.

Experiments are in progress to reduce the transients following a fueling pellet to a level acceptable for ITER by optimizing the RMP spectrum and the fueling pellet parameters as well as restoring some of the density reduction during the RMP. These experiments are providing optimistic results. Standard D_2 fueling pellets injected into an RMP ELM suppressed discharge at 10 Hz have been used to increase the core density from 3.7x10^{19} to 6.1x10^{19} m^{-3} within 1000 ms and suggest that constant density levels can be maintained by injecting fueling pellets at a rate of 3-4 Hz.

This paper will also summarize other recent experimental results related to ELM suppression with RMPs in ITER such as: RMP effects on energy confinement, compatibility of RMP fields with pellet fueling, RMP effects on density pump-out, and separatrix splitting during ELM suppression with RMP fields will be discussed in detail and conclusions on the viability of RMP ELM control for ITER will be given.

This work was supported in part by the US Department of Energy under DE-FCC02-04ER54698, DE-AC52-07NA27344, DE-FG02-04ER54758, DE-AC04-94AL85000, DE-FG03-01ER54615, DE-AC05-00OR22725, and DE-AC05-76OR00033.

[1] T.E. Evans, *et al.*, Nucl. Fusion **48** (2008) 024002.
[2] M.E. Fenstermacher, *et al.*, submitted Phys. Plasmas (2008).