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Annual Progress Report on DOE Grant for

LARGE EXPERIMENT DATA ANALYSIS COLLABORATION

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Grant Period: November 15, 1998 through November 14, 1999

This is the first annual progress report on the current 3-year Large Experiment Data Analysis Collaboration DOE grant DE-FG02-92ER54139. During this grant year the funding level was $150k. The participating personnel and their approximate degree of funded involvement in this research project has been as follows: J.D. Callen (PI, 8% during academic year, 0.3 summer months); C.C. Hegna (Associate Scientist, 25%); C. Ren (finished Ph.D. 7/99; postdoc, 13%, took job at UCLA 1/99); T.A. Gianakon (postdoc, 3%, took job at LANL 1/99); and graduate students S.E. Kruger (25% RA, Ph.D. completed 2/99, took job at San Diego SAIC), and K.J. Comer (DOE Magnetic Fusion Science Fellowship to 8/99, 30% RA 9/99-11/99). In addition, a subcontract from this grant for $45k was issued for the period 4/99 through 11/99 for work by PI S.E. Kruger of SAIC San Diego on "Shear Flow Effect On Tearing Modes."

Neoclassical Tearing Modes [1-6,8-12,13a,13b,13d,14,16a,17a,17c]

Studies of neoclassical tearing modes have remained the dominant area of research on this grant. This year articles and reports on our previous research projects in collaboration with GA colleagues on a new nonlinear tearing mode model [1,6], seed island excitation from geometrically coupled perturbations [3], the combination of flow shear and viscosity on magnetic islands [4,6,13d], and ITER projections [10] got published.

- A major new theoretical achievement by our group was the development [2,5,8,9,12,17c] of generalized reduced MHD equations that include flow shear effects. The potential importance of this work was recognized by its having been selected for an invited oral talk [9] at the most recent Sherwood Theory Conference. These new equations facilitate a self-consistent treatment of the effects of flow shear on neoclassical tearing modes, the study of which is just beginning [8,9,12,13b]. It is anticipated that the subcontract sublet to S.E. Kruger (now at SAIC-San Diego) will allow him to continue this research work in close collaboration with C.C. Hegna and GA colleagues, and in particular to apply the resultant theory to DIII-D data on such effects.

In addition, seed island formation induced by geometrically coupled perturbations was simulated [13a] using the neofar code, and the neoclassical tearing mode in DIII-D

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shot 86144.02250 was simulated [16a] using the NIMROD code. Also, RF stabilization of tearing modes was modeled [14]. Finally, a couple of summary-type talks were given [11,17a] in Japan on the status of neoclassical tearing mode studies.

Disruption Precursors [7,13c,13e,15,16b,17b]

The model we have constructed [7,13c] in collaboration with DIII-D colleagues for the temporal development of disruption precursors in NSC L-mode DIII-D plasmas has been published as a General Atomics report [7] and is in the process of being published in the Physics of Plasmas. This simple model is based on the temporal development of an ideal MHD instability as its beta is driven slowly through the instability threshold. Unfortunately, rather than being "the" mechanism for disruptions, it seems to be just one of many such mechanisms [15,17b]. In order to explore the topology of the magnetic flux surfaces just before the major disruption for our model, we have begun [13e,16b] to use a signal analysis code developed previously to compare ECE signals with theoretical predictions for these disruption precursors -- in particular their radial dependence, and the implications for the flux surface geometry and topology.

Grant-Related Publications

Journal Articles, Conference Proceedings Papers:

[1] C. Ren, T.H. Jensen and J.D. Callen, "Nonlinear Tearing Mode Study Using the 'Almost Ideal MHD' Constraint," Phys. Plasmas 5, 2574 (July 1998).

[2]* S.E. Kruger, C.C. Hegna and J.D. Callen, "Generalized Reduced Magnetohydrodynamic Equations," Phys. Plasmas 5, 4169 (December 1998).

[3]* C.C. Hegna, J.D. Callen and R.J. LaHaye, "Dynamics of Seed Magnetic Island Formation Due to Geometrically Coupled Magnetic Perturbations," Phys. Plasmas 6, 130 (January 1999).

[4] C. Ren, M.S. Chu and J.D. Callen, "Magnetic Island Deformation Due to Sheared Flow and Viscosity" Phys. Plasmas 6, 1203 (April 1999).

Reports (in process of being submitted for publication):

[5]* S.E. Kruger, C.C. Hegna, J.D. Callen, "Generalized Reduced MHD Equations," UW-CPTC 98-8, July 1998 (published in [2] above)

[6] C. Ren, "A Study of Tearing Modes Via Electron Cyclotron Emission From Tokamak Plasmas," UW-CPTC 98-11, July 1998 (Ph.D. thesis).

[14]* T.A. Gianakon, "Modeling of RF Stabilization of Tearing Modes," Workshop on Active Control of MHD, General Atomics, 23-25 November.

[15] J.D. Callen, "Disruption Precursors," talk at Workshop for Critical Assessment of MHD Issues in the MFE Program, Princeton Plasma Physics Laboratory, 24-26 February 1999.

[16] Posters at 1999 International Sherwood Fusion Theory Conference, Atlanta, GA, 22-24 March, in Bull. Am. Phys. Soc. 44, Part 1 (1999):

a)* T.A. Gianakon, J.D. Callen, C.C. Hegna and the NIMROD Team, "Simulation of Neoclassical Tearing Modes with NIMROD," paper KP01 92 on page 599.

b)* K. Comer, J.D. Callen, A.D. Turnbull, A. Garafolo, E. Strait, M. Austin, "Comparison of Experimental Diagnostic Signals with Stability Code Predictions," paper KP01 103 on page 601.

Seminars and other Scientific or Programmatic Presentations:

[17] J.D. Callen, seminars at JAERI, Naka, JAPAN, November 1999:

a)* "Neoclassical Tearing Modes," 2 November.

b) "Disruption Precursors," 5 November.

c)* "Generalized Reduced MHD Equations," 6 November.

*In addition to the DOE support for our DIII-D collaborators, our research contributions to these publications were supported in part by our Fusion Plasma Theory and Computation grant (DE-FG02-86ER53218 [2,3,5,8-12,13a,13b,14,16a,17a,17c]) or other sources (DOE Magnetic Fusion Science Fellowship [13e,16b] and CEA-Cadarache, France [14]).

[7] J.D. Callen, C.C. Hegna, B.W. Rice, E.J. Strait, and A.D. Turnbull, "Growth of Ideal MHD Modes Driven Slowly Through Their Instability Threshold: Application to Disruption Precursors," General Atomics Report GA-A22845, January 1999 (to be published in Phys. Plasmas).

[8]* Scott E. Kruger, "Generalized Reduced Magnetohydrodynamic Equations," UW-CPTC 99-2, February 1999 (Ph.D. thesis).

Invited Talks:

[9]* S.E. Kruger, "Generalized Reduced Magnetohydrodynamics," International Sherwood Fusion Theory Conference, Atlanta, GA, March 22-24, 1999.

Meeting Presentations:

[10]* F. Perkins, ... J. Callen et al., "Neoclassical Islands, Beta Limits, Error Fields, and ELMs in Reactor-Scale Tokamaks," paper ITER P1/11 at 17th IAEA Fusion Energy Conference, Yokohama, Japan, 19-24 October 1998.

[11]* J.D. Callen, "Neoclassical Tearing Modes," JIFT Workshop on Theory and Experiment for Confinement in Tori, NIFS, Toki, Japan, 26-28 October 1998.

[12]* S.E. Kruger, "Generalized Reduced MHD Equations," at MHD Working Group Meeting, New Orleans, 15 November.

[13] Posters at Annual DPP-APS Meeting, New Orleans, LA, 16-20 November, in Bull. Am. Phys. Soc. 43 (1998):

a)* T.A. Gianakon, J.D. Callen, C.C. Hegna, R.J. LaHaye, and the NIMROD Team, "Simulation of Seed Island Excitation for Neoclassical Tearing Modes," paper G4S 27 on page 1763.

b)* S.E. Kruger, T.A. Gianakon, C.C. Hegna, and J.D. Callen, "Numerical Simulations of Neoclassical Tearing Modes with Equilibrium Shear Flow," paper G4Q 24 on page 1751.

c) J.D. Callen, C.C. Hegna, E.J. Strait and A.D. Turnbull, "Growth of Ideal MHD Modes Driven Slowly Through Their Instability Threshold: Application to Disruption Precursors," paper G4S 20 on page 1762.

d) C. Ren, J.D. Callen and M.S. Chu, "Magnetic Island Deformation Due to Viscosity and External Momentum Source," paper G4Q 25 on page 1752.

e)* K.J. Comer, J.D. Callen, A.D. Turnbull, A.M. Garafolo, E.J. Strait, M.E. Austin, "Comparison of Experimental Diagnostic Signals with Stability Code Predictions," paper G4S 21 on page 1762.