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Annual Progress Report on DOE Grant for

LARGE EXPERIMENT DATA ANALYSIS COLLABORATION

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Grant Period: November 15, 1999 through November 14, 2000

This is the second 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 approximately $155k. 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 -- less than normal in summer because on sabbatical with UW-Madison Vilas Associate Award support for book writing); C.C. Hegna (Associate Scientist, 25%); and graduate student K.J. Comer (30% RA). In addition, this grant has provided a subcontract for $85k for the period 7/99 through 11/00 for work by PI S.E. Kruger of SAIC San Diego on "Effect of Flow Shear On Tearing Modes."

Neoclassical Tearing Modes [2-5,8-12]

Neoclassical tearing modes have now entered the mainstream of tokamak research. One indication of this was the featuring of it in the ITER MHD instabilities paper [2] at the 1998 Yokohama meeting, of which we (along with many colleagues throughout the world) were co-authors. In addition, this past year a number of talks were given [3-5,12] on various aspects of neoclassical tearing modes and their impacts in tokamak plasmas. At present, we are anxiously awaiting the DIII-D electron cyclotron heating and current drive feedback experiments to see if neoclassical tearing modes can be stabilized according to our theoretical model, or if the theory needs to be modified.

A major question in the application of neoclassical tearing mode theory to realistic aspect ratio toroidal plasmas such as DIII-D is: what is the effect of shear in the toroidal flow velocity on toroidicity-induced mode coupling? Both differential rotation between surfaces and flow shear at the rational surfaces can be important both in determining the linear growth rates of tearing modes and in the nonlinear excitation of tearing modes induced by sawtooth crashes. To explore these effects we have been developing an efficient new code NEAR [8] that is based on the FAR code and the Generalized Reduced MHD (GRMHD) equations [Kruger, Hegna, Callen, Phys. Plasmas 5, 4169 (1998)]. The primary work this year has been on running tearing mode [9] and 1/1 resistive kink mode [10] benchmark cases against the full FAR and reduced FAR

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codes. After correcting some coding, the NEAR code has been shown to be more accurate than the reduced FAR code, and much faster and at least as accurate as the full FAR code. A summary of these results and plans for using the NEAR and NIMROD codes to explore DIII-D type plasmas over the next year are summarized in [11].

Disruption Precursors [1,3,6a,6b,7]

This past year our joint paper [1] on the disruption precursor model for L-mode NCS high beta DIII-D plasmas was published. This work has also been used to buttress the validity of the application of the ideal MHD instability model to DIII-D [6a] and tokamak burning [3] plasmas. In this model ideal MHD instabilities are driven slowly through their instability threshold. Then, the instability grows linearly as exp(t^{3/2}) until the magnetic topology of the equilibrium plus perturbation begins to overlap. A code was developed to implement this model using the GATO linear eigenmode structure to try to ascertain [6b] the radial region of the plasma where the model first breaks down and the plasma disruption begins; unfortunately, while it seemed that the breakdown may have been occurring first at the edge, neither the ECE signals nor magnetic topology calculations were accurate enough to derive a firm conclusion. Finally, because of the need for investigating ideal MHD instability and growth rates and eigenmode structure in the vicinity of the instability threshold and the fact that well-resolved GATO runs take a lot of computer time, we have begun exploring [7] an idea put forth by Steve Cowley some years ago to determine these changes perturbatively in delta-W space.

Grant-Related Publications

Journal Articles, Conference Proceedings Papers:

[1]* 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," Phys. Plasmas 6, 2963 (August 1999).

[2]* F. Perkins, A. Bondeson, R. Buttery, J. Callen, J. Connor, A. Garofalo, D. Gates, R. Harvey, C. Hegna, T. Hender, G. Huysmans, Y. Kamada, R. La Haye, A. Pletzer, M. Rosenbluth, T. Taylor, J. Wesley, H. Wilson, and H. Zohm, "Neoclassical Islands, Beta-Limits, Error Fields, and ELMs in Reactor-Scale Tokamaks," Nuclear Fusion 39, 2051 (November 1999).

Meeting Presentations:

[3]* C.C. Hegna on behalf of the MHD/MFE Sub-Group, "Burning Plasma Experiments and MHD Issues," 1999 Fusion Summer Study, Snowmass, CO, July 22, 1999.

[4]* C.C. Hegna, "Pressure Driven Magnetic Islands in Toroidal Confinement Systems," US-Japan Workshop on Physics of High-beta, General Atomics, San Diego, CA, September 8, 1999.

[5]* C.C. Hegna, "Status and Issues in Neoclassical Tearing Mode Theory," Workshop on Theory and Computation of Toroidal Classical and Neoclassical Tearing Modes, Los Alamos National Laboratory, Los Alamos, NM, October 21, 1999.

[6] Posters at Annual DPP-APS Meeting, Seattle, WA, 15-19 November, in Bull. Am. Phys. Soc. 44 (November 1999):

a) A.D. Turnbull, L.L. Lao, E.J. Strait, M.S. Chu, J.R. Ferron, T.H. Osborne, P.A. Politzer, R.D. Stambaugh, T.S. Taylor, A.M Garofalo, E.A. Lazarus, J.D. Callen, K. Comer, B.W. Rice, "Comparison of Ideal MHD Stability Predictions with MHD Behavior in DIII-D," poster CP1 85, p 77.

b) K. Comer, J. Callen, C. Hegna, E. Strait, A.D. Turnbull, "Evolution of Flux Surfaces During a Slowly-Driven MHD Precursor," poster CP1 86, p 77.

[7]* Poster at 2000 International Sherwood Fusion Theory Conference, Los Angeles, CA 27-29 March, 2000: K. Comer, J. Callen, C. Hegna and S. Cowley, "Macroscopic Stability of Perturbed Screw Pinch Equilibria," poster 2C03.

Web-accessible documentation and informal reports:

[8] S.E. Kruger, Web site for NEAR: http://haven.saic.com/near

[9] S.E. Kruger, Tearing mode benchmark: http://haven.saic.com/near/TMComparison.html

[10] S.E. Kruger, "Benchmark of NEAR for a 1/1 Resistive Kink Mode:" http://haven.saic.com/near/RKComparison.html

[11] Scott Kruger, Yearly Progress report and Statement of Work on "Effect of Flow Shear on Tearing Modes," June 12, 2000: http://haven.saic.com/~kruger/Callen/Progress%20Report.html

Seminar Talks:

[12] S.E. Kruger, "Neoclassical Tearing Modes: Analytic and Numerical Theory," Integrated Modeling Meeting, General Atomics, March 2000.

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