MEETING REPORT

SUMMARY OF THE ELEVENTH INTERNATIONAL CONFERENCE ON NUMERICAL SIMULATION OF PLASMAS, MONTREAL, QUEBEC, CANADA, JUNE 25-28, 1985

The conference was attended by ~100 participants representing most of the major laboratories active in numerical simulation in North America, Europe, USSR, and Japan. A book of summaries of the presentations is available.[1]

The meeting provided a forum for both scientific interaction with colleagues and reflection on the very substantial progress reported in numerical simulations at a time when increasing computational power is being brought to bear on the numerical problems. Much of this effort is directed toward the development of three-dimensional codes and to the preparations for a new generation of computers such as the CRAY-2.

Major developments of the past two years were presented, treating the various areas where numerical simulation contributes to the fusion program. These include the study of basic physics phenomena, the interpretation of experimental data, the design of new experiments, the exploration of new concepts and ideas, and the study of innovative configurations with fully three-dimensional magnetohydrodynamic (MHD) codes. Over 75 individual papers were presented at the conference. In addition, an invited review lecture by David Nelson (U.S. Department of Energy) on Numerical Simulation and the Magnetic Fusion Energy (MFE) Program gave a useful overview of the role of numerical simulation in the fusion program, of some of the results obtained, and of the main features of the national MFE network. Plans for the development of this network to meet future simulation needs and preparation for the CRAY-2 generation were also discussed. Examples of the favorable impact of numerical simulation on experiments are the case of ray tracing in the Princeton Large Torus tokamak, which helped increase efficiency of current drive experiments and studies of surface processes in plasma/wall interactions. A further example of the symbiosis of simulation and experiment is the reversed-field pinch program, where experiments show spontaneous generation of toroidal flux to maintain field reversal, violating classical resistive flux diffusion. Three-dimensional MHD simulation showed that tearing mode interactions can maintain field reversal. Some of the future simulation needs, identified in this review lecture, are (a) nonlinear stability limits for field-reversed configurations with finite gyroradius ions, (b) alpha-particle dynamics in burning plasmas, especially tokamaks, (c) methods providing the insight required for the improvement of fusion configurations to show higher beta, better confinement, reduced impurities, etc., and (d) better treatment of turbulent plasmas.

The conference was organized in three morning oral sessions and three evening poster sessions. Two oral presentations opened the first day on techniques in numerical simulations: R. Lewis et al. on discrete particle Lagrangian techniques, especially in the single-species Vlasov-Poisson system in one dimension, and M. Felix et al. on rescaling methods and the evolution of charged particles in a time-varying magnetic field. The two remaining oral presentations were on beams. In the first, J. Wagner presented the three-dimensional nonlinear relativistic electron beam propagation code DYNADISC. Results obtained using this code to model the hose instability of rotating annular beams were presented. J.-M. Dolique presented a multifluid study as a function of beam parameters for an electron beam pulse propagating in the atmosphere, investigating in particular the concept that a hole should be progressively bored in the atmosphere if a pulse train is used rather than a single pulse.

The poster session of the first day was concerned with beams, transport, ray tracing, and particle simulation. It was also dominated by three-dimensional codes such as the beam-plasma code ARGUS (A. Mankofsky et al.). We also mention the ray-tracing code of R. C. Goldfinger and D. B. Batchelor used to study the propagation and absorption of electron cyclotron waves in the Advanced Toroidal Facility stellarator, the work of Kritz et al. on modeling electron transport in plasmas subject to electron cyclotron heating (ECH), and the work of I. P. Shkarofsky on the second harmonic cyclotron absorption and ray tracing in tokamak plasmas with warm and mildly relativistic dielectric tensor elements. Three-dimensional simulation of ECH was also presented using a quasi-linear code describing electron cyclotron heating and current drive in a bounce-averaged Fokker-Planck/radio-frequency system (R. W. Harvey et al.). Particle codes were well represented in this first poster session, with a two-dimensional electromagnetic direct-implicit plasma simulation code (D. Hewett and B. Langdon), a magneto-inductive particle code with perpendicular guiding center electron motion (J. Geary et al.), a low-frequency fully electromagnetic code (S. Rigopoulos and T. Tajima), an implicit electromagnetic particle code (D. C. Barnes et al.), an implicit particle-in-cell algorithm for intense relativistic beam simulations (M. Jones et al.), and a discrete Hamiltonian plasma simulation code (C. Menyuk and V. Decyk).

The second day of the conference was MHD day. It was dedicated to the memory of Ray Grimm (who suffered a fatal heart attack in 1984), in recognition of his contributions to computational plasma physics. The first four oral presentations covered the topics of numerical approach to toroidal resistive MHD instabilities (R. Storer), optimizing tokamak design (J. Helton and J. Greene), computation of MHD equilibria by a quasi-inverse finite hybrid element approach (R. Gruber et al.), and linear and quasi-linear simulations of the reversed-field pinch (A. Sykes and J. Wesson). Preparing for the CRAY-2 generation was the subject of the final oral presentation of this session and included an introduction to multitasking in the Cray Time Sharing System by H. Hicks and V. Lynch, a topic covered again the next day in an oral session by D. Anderson. Multitasking allows a single job to use more than one processor, with a consequent reduction in wall clock time and, potentially, the costs of the calculations. Large-memory jobs might be the best candidates for multitasking, since the simultaneous use of multiple processors may reduce the memory residency charge. Many of the posters presented this second day also treated MHD problems; three-dimensional and nonlinear MHD evolution were of particular interest. We mention specifically a nonvariational numerical method for finding fully three-dimensional MHD equilibria (H. Greenside and A. Reimann), a nonvariational ideal MHD stability code for axisymmetric toroidal plasmas (C. Z. Cheng and M. S. Chance), a three-dimensional simulation code for nonlinear incompressible resistive MHD in a periodic cylinder (P. Kirby), and nonlinear MHD evolution of the CTX spheromak (A. M. Mirin and A. C. Sgro). Since the recent development of three-dimensional configuration codes, considerable effort has been devoted to their validation. A comparison of two- and three-dimensional MHD equilibrium and stability codes was presented by F. Herrnegger and J. L. Johnson, who compared the stability predictions of the stellarator expansion model for a straight $l = 2$ stellarator to those of the BETA code as toroidal curvature is introduced. We also note the work on resistive MHD numerical calculations in toroidal geometry (L. A. Charlton et al.) and on three-dimensional equilibrium as an ohmic steady state (W. Park et al.).

On the third day, the oral sessions addressed various other topics in numerical simulations, which included problems of bounded particle simulation (C. K. Birdsall et al.), the use of the multitasking software on the Cray multiprocessors for parallel computation of tandem mirror plasma equilibria (D. Anderson), numerical properties of gyrokinetic plasma (W. W. Lee), and simulation codes for electrode/plasma interaction in spherical and cylindrical geometry (A. Calder and J. Laframboise). The poster sessions covered many new techniques for particle simulation and numerical calculation: approaches to the existence and stability of boundary equilibria in finite plasma simulations (R. Bass et al.), a fast direct solution of Poisson's equation for large three-dimensional problems: CYCLOP (C. L. Chang et al.), Monte Carlo charged particle and photon transport in particle-in-cell codes (T. J. Kwan et al.), Monte Carlo treatment of nonlinear collisional effects in charged-particle transport (T. A. Oliphant et al.), calculation of laser light transport, deposition and scattering on a Lagrangian *R-Z* mesh (A. Friedman), codes related to tandem mirrors (W. M. Nevins et al. and B. I. Cohen et al.), high-order spline interpolations in the particle simulation (H. Abe et al.), and applications of shape-preserving splines for the numerical solution of one- and two-dimensional partial differential equations (M. Shoucri). We also mention the work on the interactive analysis of the output from a system of codes (V. Lynch et al.).

In conclusion, the conference was characterized by the presentation of substantial contributions to the development and application of three-dimensional codes in the fusion program, to the providing of the insight required for the improvement of fusion concepts and to the preparations for the CRAY-2 generation. The 12th conference in this series will take place in San Francisco in 1987 and will be organized by the National Magnetic Fusion Energy Computer Center at Lawrence Livermore National Laboratory.

R. A. Bolton

Project Tokamak de Varennes
Varennes, Quebec
Canada J0L 2P0

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Richard A. Bolton was awarded a BSc degree with honors in physics and mathematics by McGill University in Montréal in 1960 and an MSc in solid state physics by the same institution in 1963. He received a PhD degree in plasma physics from the Université de Montréal in 1966.

After two years on the faculty of the Université de Montréal, he joined the Culham Laboratory of the U.K. Atomic Energy Authority where he did experimental research on the plasma confinement properties of stellarators. In 1973 he returned to Canada and joined the Institut de Recherche d'Hydro-Québec, near Montréal, where he is now the program manager for fusion and project manager of the Tokamak de Varennes high duty factor experiment.

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REFERENCE

1. *Proc. 11th Int. Conf. Numerical Simulation of Plasmas*, Montréal, Canada, June 25-27, 1985.