MEETING REPORT

SUMMARY OF THE EIGHTH U.S. COMPACT TOROID SYMPOSIUM/NINTH U.S.–JAPAN WORKSHOP ON COMPACT TOROIDS, COLLEGE PARK, MARYLAND, JUNE 4–5, 1987

INTRODUCTION

The combined symposium/workshop was held at the Center of Adult Education of the University of Maryland. The conference format consisted of seventeen 15- to 20-min invited talks, with another 42 poster papers distributed in three sessions. The $1\frac{1}{2}$-h-long poster sessions were interspersed with the invited talks. There were 25 papers on spheromaks, 20 on field-reversed configurations (FRCs), and 17 on other subjects related to compact tori.

Eighty-two participants attended the meeting, including 8 from Japan, 2 from the Federal Republic of Germany (FRG), and 2 from Australia. The practice of mixing the subject matter in each session was well received. The schedule, however, was overfull, and could easily have occupied 2 full days rather than the $1\frac{3}{4}$ days allotted. Nevertheless, discussion was vigorous and the interchange was productive.

SUMMARY

Spheromaks

The interval since the last compact toroid meeting was characterized by increasingly sophisticated diagnostics applied to several existing spheromak devices. In the S1 device, evidence for onset of a relaxation oscillation has been seen, with current gradually peaking, followed by the appearance of an $m = 1$, $n = 2$ kink that serves to convert some poloidal to toroidal flux, reestablishing the Taylor state. Studies of the mode structure in a spheromak plasma also were reported in both the compact toroid experiment (CTX) device and in Proto S1, helping to elucidate the formation, sustainment, and decay phases of the configuration. An observation received with great interest was that of the Heidelberg group, showing that a metallic rod inserted along the axis of the spheromak stabilizes it against gross instability. A central rod was also used by the Osaka group, with the purpose of increasing shear stabilization for better energy confinement.

The strong tendency of the plasma to fall spontaneously into the Taylor state continues to be confirmed in many laboratories. The Colorado group operated a reversed-field pinch device as a spheromak, observing rapid conversion of poloidal to toroidal flux. At the University of Washington (UW), the relaxation rate to a Taylor state of configurations formed by a conical theta pinch were studied. Analysis of plasma formation and decay using the concept of magnetic helicity was presented by the University of Tokyo group and papers from Los Alamos National Laboratory (LANL) (Jarboe and Marklin). Helicity injection experiments on a tokamak device were also reported by Bellan.

Scaling measurements were reported in CTX, showing that the core temperature scaled upward with j_{tor}/n_e up to $\sim 1.5 \times 10^{-14}$ A·m, then leveled off. In this work, only a very weak inverse dependence of T_e was seen on n_e. The constant beta scaling seen in other work was not observed. A size modification to CTX showed energy content scaling with R^5, while the energy decay time scaled with R^2. In S1, measurements showed that during the (transient) current peaking phase, both particle confinement time and nT product increase approximately as j^2. This would be an exciting result if it held for steady-state plasmas. The peak temperature reported in S1 was 110 eV, and the particle confinement time was ~ 300 μs. Since all these plasmas decay in time, current drive is of great interest. Boozer presented a novel theory discussing application of inductive f-Θ pumping current drive in a spheromak.

Flows in spheromaks are attracting increasing attention. Researchers at the University of Maryland (UM) have reported the existence of velocity fields during formation and the theory of magnetohydrodynamic (MHD) flow equilibria has been studied by the Heidelberg group. Translated spheromaks were studied by the UW group in merging experiments, and by the Lawrence Livermore National Laboratory (LLNL) group in accelerating compact toroids to very high velocities, and in theoretical studies at LANL aimed at using the spheromak configuration to facilitate acceleration of solids to hypervelocities.

In an unsuccessful attempt to improve the confinement of a gun-produced spheromak, the Osaka University group added a "choking" coil to close off the flux conserver after injection. In another gun-type spheromak at Himeji, an intermediate section between gun and flux conserver was used to increase the poloidal flux of the configuration before it is injected onto the flux conserver.

A three-dimensional MHD code (Mirin and Sgro) has been applied to the decay phase of a spheromak showing that inclusion of Hall terms leads to poloidal plasma rotation and apparently to the destruction of magnetic surfaces.

The force-free magnetic fields of a spheromak inspired Furth to discuss similar configurations as a means to produce ultra-high-field superconducting magnets.

New experimental devices (MS and TS-3), both using the θ-z formation scheme, were reported by the UM and Tokyo groups. MS is a high-B-field machine, while the Tokyo device features electrode structures to form a wide variety of configurations. Plans for a compression experiment in S1 were discussed by Motley and Levinton.

FRCs

The anomalous stability of the FRC configuration against the $n = 1$ internal tilt continues to attract attention at several laboratories. Work at LLNL, LANL, Science Applications International, and Spectra Technologies was reported in which two- and three-dimensional MHD theory and simulations investigated the effects on stability of finite Larmor radius, rotation, and use of a two-fluid approach. The observed stability of FRCs remains anomalous. Assuming that the predicted tilt instability will eventually show up, Schamiloglu et al. are working on production of a rotating proton beam that could be merged with an FRC to stabilize it. In experiments reported here, the beam excited magnetosonic waves in the plasma into which the ring was injected. The theory of stabilization of the $n = 2$ rotational instability was refined in a paper by Ishimura.

Looking at the region of the field null, Sgro presented a model in which microturbulence accounts for the anomalous resistivity. Stark and Miley presented a theory of the electron currents in this region. An interesting new theory presented by Berk suggests that in a reactor, charged fusion products could help maintain the plasma current.

Increasingly careful diagnostics are being applied to these experiments, attested to by work on the mature experiments at The Pennsylvania State University (PSU), Osaka University, and LANL. Use of a six-chord interferometer on LSM (large version of FRX-C at LANL) yielded quite detailed electron density profiles of the FRC plasma. At PSU a variety of diagnostics, including scattering, interferometry, pressure probes, and integrated light measurements yield data for careful comparison with a one-dimensional MHD code, with the result that classical transport seems to describe the observations well.

Translation experiments by the Osaka University group attempted to elucidate the growth of a nonsymmetric azimuthal B field seen after the first bounce. At Nihon University, an axial current was imposed on an FRC, with the result that for sufficiently small currents, the lifetime of the configuration was increased.

The new slow formation FRC at UW has been operated, with flux buildup times of ~ 25 μs, with average beta close to 0.5. At LANL, a 50% larger version of FRX-C (LSM) has been operated. Despite several improvements to the operation, as attempts were made to increase trapped flux, strong axial contractions were observed, with accompanying degradation in confinement. Studies are under way to identify the cause of this behavior. A clever way to increase the density of an FRC plasma beyond limits set by formation dynamics was to use solid D_2 injection, discussed by Hugrass et al.

Plans for new experiments were disclosed by two groups. A compressed FRC experiment featuring effective 1-GW power input is contemplated at LANL, while design of the LSX (large S_x) experiment was discussed by the Spectra Technologies group.

Workers from FRG (Tuczek) and Australia (Donnelly et al.) reported on recent work with the Rotomak concept, in which the toroidal current is driven by a rotating transverse magnetic field. Theory of current drive in compact tokamaks was also discussed by Donnelly, and a self-consistent, two-fluid theory applied to a Rotamak reactor was presented by Sperling and Moses.

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January 25, 1988