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Recent Developments in Linear Theta-Pinch Research: Experiment and Theory*

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High energy plasmas of fusion interest can be generated in linear theta pinches. However, end losses present a fundamental limitation on the plasma containment time. This paper discusses recent progress in end-loss and end-stopping experiments and in the theoretical understanding of linear theta-pinch physics.

1. EXPERIMENTS

With the elimination of end losses as the ultimate objective, the following experiments have been carried out on the high-energy ($I_0 + I_1 = 3.2$ MA, $B_0 = 1.5 \times 10^4$ G), 5-m Rayite IV-2 linear theta pinches: (1) for the definition of the characteristic end-loss times, and the electron flow (2) near theta-pinch coil ends, and (3) material end-stop experiments designed to eliminate axial particle flow. The main result at present is the 10-fold increase in energy containment time achieved with tip end plugs.

2. THEORETICAL CONSIDERATIONS

1. The electron particle end-loss rate, Γ_e , has been compared with collisional electron drag and theory. The resulting end-loss time $\tau_e = 1/\Gamma_e$ is of the order of the coil length and $\Gamma_e \propto I_0 + I_1$, is independent of the coil external magnetic field of the plasma.

2. The electron flow near the coil ends has been measured. The flow is directed towards the ends of the coil and is of the order of 10^{18} electrons/cm² s. The flow is independent of the coil external magnetic field of the plasma.

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observed with the high-Z PN and SiO_2 plugs indicating that η_e is dominated by plasma flow to the end plugs and z -dependent energy-loss processes.

3. The surface ablation profile of the quartz plugs is Gaussian with a radius about equal to the plasma column radius. Less than 1 μm of plug material was ablated per discharge and $< 1\%$ of the plasma energy is deposited on the plug surface per discharge.
4. A plasma ablation layer 1-2 μm thick develops on the plug surface $\sim 1-2 \mu\text{s}$ after formation of the plasma column. For the SiO_2 plugs the radial density profile within 2 cm of the plug surface is Gaussian. At axial positions $> 2 \text{ cm}$, the profile becomes irregular with the bulk of ablated material flowing along the outer edge of the main plasma column. For the LiF plugs, at positions $> 1 \text{ cm}$, the density profile is strongly peaked both along the plasma column axis and at the column outer edge.

II. THEORY

A. Gasdynamic Studies

The results of further numerical studies of plasma flow were presented, which were obtained by solving the time-dependent equations for the gasdynamic flow in the dimensions. The results are compared with experimental data for the plasma flow, with and without plug material. The differences between the experimental and calculated results are discussed, but not in the context of the present study. The results of the numerical studies are presented in the form of plots of the plasma flow parameters versus time and position. The results show that the plasma flow is highly irregular and that the plasma column is highly unstable. The results also show that the plasma flow is highly dependent on the initial conditions and the geometry of the system.

agreement with experiment is obtained assuming conditions near complete end-shorting.

2. Magnetoacoustic Heating of a Collisionless Pinch

Magnetoacoustic heating permits preferential ion heating when an appropriate dissipative mechanism exists. For a linear pinch, magnetoacoustic heating would not impose a limitation on end-stoppinging schemes and may allow lower values of the induced RF electric field than are required when implosion heating is used alone. Magnetoacoustic heating also may be practical for reversed-field pinches.

Using the linear-field model, we have studied magnetoacoustic heating of a screw pinch in a collisionless plasma regime theoretically, including the effects of finite ion gyroradius. Heating times and associated induced RF electric fields have been calculated for a 200 kG, 10 cm radius field-reversed configuration. Alternative mechanisms for converting magnetoacoustic wave energy into thermal energy.

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