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Reduction of Large-scale Turbulence and Optimization of Flows in the Madison Dynamo Experiment

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The Madison Dynamo Experiment seeks to observe a magnetic field grow at the expense of kinetic energy in a flow of liquid sodium. The enormous Reynolds numbers of the experiment and its two vortex geometry creates strong turbulence, which in turn leads to transport of magnetic flux consistent with an increase of the effective resistivity. The increased effective resistivity implies that faster flows are required for the dynamo to operate. Three major results from the experiment will be reported in this talk. 1) A new probe technique has been developed for measuring both the fluctuating velocity and magnetic fields which has allowed a direct measurement of the turbulent EMF from $< v \times b >$. 2) The scale of the largest eddies in the experiment has been reduced by an equatorial baffle on the vessel boundary. This modification of the flow at the boundary results in strong field generation and amplification by the mean velocity of the flow, and the role of turbulence in generating currents is reduced. The motor power required to drive a given flow speed is reduced by 20%, the effective Rm, as measured by the toroidal windup of the field(omega effect), increased by a factor of $\sim$2.4, and the turbulent EMF (previously measured to be as large as the induction by the mean flow) is eliminated. These results all indicate that the equatorial baffle has eliminated the largest-scale eddies in the flow. 3) Flow optimization is now possible by adjusting the pitch of vanes installed on the vessel wall. An analysis of the kinematic prediction for dynamo excitation reveals that the threshold for excitation is quite sensitive to the helical pitch of the flow. Computational fluid dynamics simulations of the flow showed that by adjusting the angle of the vanes on the vessel wall (which control the helical pitch of the flow) we should be able to minimize the critical velocity at which the dynamo onset occurs. Experiments are now underway to exploit this new capability in tailoring the large-scale flow.