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3D MHD simulation of Caltech Plasma Jet Experiment and Implications for Astrophysical Jets[1]

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Magnetic fields are believed to play an essential role in astrophysical jets with observations suggesting the presence of helical magnetic fields. In this talk we present 3D ideal MHD simulations of the Caltech plasma jet experiment using a magnetic tower scenario as the baseline model. Magnetic fields consist of an initially localized dipole-like poloidal component and a toroidal component that is continuously being injected into the domain. This flux injection mimics the poloidal currents driven by the anode-cathode voltage drop in the experiment. The injected toroidal field stretches the poloidal fields to large distances, while forming a collimated jet along with several other key features. Detailed comparisons between 3D MHD simulations and experimental measurements provide a comprehensive description of the interplay among magnetic force, pressure and flow effects. In particular, we delineate both the jet structure and the transition process that converts the injected magnetic energy to other forms. With suitably chosen parameters that are derived from experiments, the jet in the simulation agrees quantitatively with the experimental jet in terms of magnetic/kinetic/inertial energy, poloidal current, jet radius and jet propagation velocity. Specifically, the jet velocity in the simulation is proportional to the poloidal current divided by the square root of the jet density, in agreement with both the experiment and analytical theory. This work provides a new and quantitative method for relating experiments, numerical simulations and astrophysical observation, and demonstrates the possibility of using terrestrial laboratory experiments to study astrophysical jets.

[1]The work has been done under the collaboration between Caltech Bellan group and LANL Li group.