DPP15-2015-000612

Abstract for an Invited Paper
for the DPP15 Meeting of
the American Physical Society

Using 1D theory to understand 3D stagnation of a wire-array Z pinch in the absence of radiation[1]

EDMUND YU, Sandia National Laboratories

Many high-energy-density systems implode towards the axis of symmetry, where it collides on itself, forming a hot plasma. However, experiments show these imploding plasmas develop three-dimensional (3D) structures. As a result, the plasma cannot completely dissipate its kinetic energy at stagnation, instead retaining significant 3D flow. A useful tool for understanding the effects of this residual flow is 3D simulation, but the amount and complexity of information can be daunting. To address this problem, we explore the connection between 3D simulation and one-dimensional (1D) theory. Such a connection, if it exists, is mutually beneficial: 1D theory can provide a clear picture of the underlying dynamics of 3D stagnation. On the other hand, deviations between theory and simulation suggest how 1D theory must be modified to account for 3D effects. In this work [1], we focus on a 3D, magnetohydrodynamic simulation of a compact wire-array Z pinch. To provide a simpler background against which to test our ideas, we artificially turn off radiation during the stagnation phase. Examination of the initial accumulation of mass on axis reveals oblique collision between jets, shock accretion, and vortex formation. Despite evidence for shock-dominated stagnation, a 1D shockless stagnation solution is more appropriate for describing the global dynamics, in that it reproduces the increase of on-axis density with time. However, the 1D solution must be modified to account for 3D effects: the flows suggest enhanced thermal transport as well as centrifugal force. Upon reaching peak compression, the stagnation transitions to a second phase, in which the high-pressure core on axis expands outward into the remaining imploding plasma. During this phase, a 1D shock solution describes the growth of the shock accretion region, as well as the decrease of on-axis density with time. However, the effect of 3D flows is still present: the on-axis temperature does not cool during expansion, which appears due to “channels” of plasma carrying heat to the core center.

[1] E.P. Yu, A.L. Velikovich, and Y. Maron, Phys. Plasmas 21, 082703 (2014)

[1]Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockhead Martin Company, for the National Nuclear Security Administration under DE-AC04-94AL85000.