The influence of edge viscosity on plasma instabilities

G. O. Ludwig

Instituto Nacional de Pesquisas Espaciais, 12227-010, São José dos Campos, SP, Brazil

The interface between the plasma edge and its surroundings affect both the structure of plasma instabilities and the quality of confinement. According to well established procedures in MHD theory, the boundary conditions for the analysis of free-boundary instabilities is set by the flow of energy, mass, or flux across the boundary. However, ideal MHD disregards the role of viscosity in fluid motion. Even considering that viscosity effects are negligible for large scale instabilities in the core of high temperature plasmas, the effect of viscosity in the boundary is similar to surface tension, having a strong influence on high order modes of oscillation near the plasma edge. In water the balance between the forces of gravity and surface tension marks the transition from gravity waves to capillary waves [1].

This paper reports two instances where edge viscosity may be important in the behavior of natural as well as laboratory plasmas. In the first example the turbulence associated with the Rayleigh-Taylor instability, which is driven during the contracting stage of the decaying return stroke of a lightning discharge, creates anomalous viscosity that defines the spatial structure of bead lightning [2,3]. In the second example the kink modes in circular cylindrical plasmas are examined by taking into account the effect of viscosity in the boundary. It is shown that the $m=1$ kink mode is barely changed, but the higher order $m\geq 2$ modes are significantly damped if the collisionality is high. This has interesting implications for magnetic fusion, since the ballooning modes, which set a limit to the maximum pressure that can be confined in a tokamak, could be strongly affected. One may conjecture that anomalous ion viscosity associated with drift wave turbulence increases the surface tension thus leading to improved confinement. Since the anomalous viscous stress has a non-Newtonian character, one would have eventually a situation of bifurcation, allowing for drastic changes in the equilibrium. These topics are presently under investigation. One should point out that improved confinement by surface effects is the standard operational scenario envisioned for ITER, in conditions that have not been fully explained to date.

[1] B. B. Kadomtsev, *Phénomènes Collectifs dans les Plasmas*, (Éditions MIR: Moscou, 1979), p.58.
[2] G. O. Ludwig and M. M. F. Saba, "Macroscopic instabilities in lightning", in *X Latin American Workshop on Plasma Physics combined with the 7th Brazilian Meeting on Plasma Physics, São Pedro, SP, Brazil, 2003*.
[3] G. O. Ludwig and M. M. F. Saba, "Bead Lightning Formation", submitted to *Phys. Rev. E*.