AFE DYNAMIC EFFECTS IN INHOMOGENEOUS PLASMAS

by

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The Microwave Reflectometer Ionization Sensor (**MRIS**) is an instrument on the Aeroassist Flight Experiment (**AFE**) satellite which will be deployed from the space shuttle.

The flow characteristic around a hypersonic bluff reentry vehicle will be measured by the **AFE**. The general mission of the **MRIS** is to measure the electron density within the range from 10^{12} to 10^{15} electrons per cm^3 and determine the distance to the location of each measured density from the surface of aerobrake. These measurements will be compared with prior aerothermodynamic computer code predictions. Since a knowledge of plasma dynamic effects is important for **MRIS** design and post-flight analysis, it is of interest to consider any possibility of plasma dynamic effects and especially in inhomogeneous plasmas.

Of particular interest is the need to study plasma dynamic effects that may emerge from a flow field stationary state that has been determined without regard to electric or magnetic fields. Such a flow field state will not in general be stationary with respect to electric and magnetic effects. One must, therefore, start any plasma stability analysis from a slightly different starting point, namely are that is modified from the given stationary state in such a way as to remove the most rapidly changing electric effects. Some of the plasma effects to be considered are as follows. A nonuniform system has a natural tendency to release this extra amount of free energy to approach a uniform state of thermodynamic equilibrium. Applying the magnetic field to the plasma places certain constraints on the motion of charged particles. Ordinary relaxation processes through collisions may not have an effective mechanism to approach equilibrium. The onset of an instability may be an alternative avenue relaxations would, thereby, result in the plasma. The effects of force fields upon the motion of charged particles also must to be considered in many cases. Such forces include gravity, electric field, and centrifugal force due to the curvature of the magnetic lines of force. These force fields or inhomogeneities acting together with the magnetic field then produce various drift motions of charged particles. Such particle drifts are essential to the understanding of various instabilities in inhomogeneous plasmas.

The neutral gas will not allow a common drift velocity of ions and electrons ($\mathbf{W_D}$) to be attained in electric and magnetic fields. Therefore, there will be a residual electric field which attempts to drive a current and build up a space charge. This charge tends to redrive the electric field and produces a magnetic force (**JxB**). This force tends to increase drift velocity ($\mathbf{W_D}$). The space charge must exist only at the boundaries and will be established on a time scale commensurate with the propagation of an electrostatic wave (i.e., the electron thermal velocity).

Any initial values involving **VxB** must first allow the space charge sheath to form so the $\mathbf{V_0xB}$ term is removed from the problem and the space charge sheath will adjust itself as nearly as possible which tends to cause the residual **VxB** to be reduced throughout the flow field. This of course proceeds on the same fast time scale. At this point, the local electric field will not be totally zero since the velocity field, the temperature, and density fields are also arbitrary. Therefore, the medium has electric stresses that can only be relieved by readjustment of the velocity, temperature, and density fields. This readjustment must pass through a phase in which the Navier-Stokes equation is not strictly valid (or for which the effective transport coefficients cannot be known). The gas still moves under pressure and density gradients, but with higher ordered terms present.

Only after all the readjustments have occurred will there be an "equilibrium" state whose stability can be examined to see where and if electron density fluctuations occur. The purpose of the present research is to investigate some generic flow field density and velocity profiles to approximate this "equilibrium" state.