A Consistent Fluid Approach (CFA) to model electrical discharges

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***Abstract* — Widely known, corona discharges arise within those regions where electric fields are very strong, usually as a result of a sharp electrode like needles, blades, wires, etc. One of the most remarkable features of corona discharges is the highly non-uniform spatial distribution of the corresponding electric field. Besides, the coupled system consisting of the Poisson equation (electric potential problem) along with the problem related to the transport of species becomes highly nonlinear, due to the dependency on the electric field distribution of the transport coefficients and the reaction rates in the continuity equations for charged species (cold plasma approximation).**

Under these circumstances, the robustness of the numerical scheme is crucial to deal with numerical instabilities linked with rapid evolution of electrical discharges, where shock fronts and discontinuities may be developed in the vicinity of sharp electrode [1,2]. Nonetheless, in such a conditions others instabilities may also emerge as a consequence of the limit of validity of fluid approach to describe the dynamics of species.

This work presents a total-variation-diminishing scheme based on the finite volume method together with a physical limiter to combine the numerical and theoretical problem as a whole. The concept of limiter is used over physics which describes the problem avoiding those physical instabilities what appear when cold plasma approximation try to compute the evolution of macroscopic variables where the Boltzmann equation stops to remain valid. And, because of the Boltzmann equation underlies in the basis of fluid approach wherever this limiter indicates a failure on some of the implicit hypotheses into the Boltzmann equation, so too will onto corresponding fluid equations.

To test the numerical efficiency of the scheme and thereby the validity of this novel and consistent viewpoint about fluid approach, we have chosen the classical problem carried out by Morrow [1]. This study addresses the evolution of negative corona discharge in O2. Nevertheless, unlike the original problem carried out in 1.5D, we use a full 2D (axisymmetric perspective) computation to improve the original picture.

References [1] R. Morrow, "Theory of negative corona in oxygen," Phys. Rev. A, vol. 32, no. 3, pp. 1799–1809, Sep. 1985. [2] F. J. Durán-Olivencia, F. Pontiga, and A. Castellanos, "Multi-species simulation of Trichel pulses in oxygen," J. Phys. Appl. Phys., vol. 47, no. 41, p. 415203, Oct. 2014.