# Numerical analysis of time-evolution starting from equilibrium states of electrically non-neutral two-fluid plasmas by 2D3V PIC simulation

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Two-fluid plasma models, which describe ion-electron plasmas as two individual fluids, play a role in detailing the dynamics and deriving novel equilibria of the plasma. In addition, current enthusiastic efforts to verify two-fluid effects in plasmas such as transport of relative canonical helicity[1] or turbulences in tokamak edge region[2], require electrically non-neutrality of plasmas. To investigate how electrically non-neutrality affects the confinement of the plasmas, one way would be to find stable equilibrium states in geometrically simple configurations. Therefore, as one of the simple configurations, we have been considering an infinitely long cylindrical electrically non-neutral plasma and deriving the equilibria numerically. However, its stability has not been analyzed. In this presentation, we show numerical analysis of time-evolution starting from equilibrium states of counter-differential rigid-rotation equilibria of electrically non-neutral two-fluid plasma[3] by 2D3V PIC code[4]. In the equilibria, ion ($i^+$) and electron ($e^-$) plasmas with finite temperatures are confined cylindrically by a uniform magnetic field B exhibit corresponding rigid rotations around the plasma axis with different angular velocities $\omega_i$ and $\omega_e$, which is attributed to the contribution from the diamagnetic drift of the $i^+$ and $e^-$ plasma owing to its finite pressures. While the equilibrium state has been experimentally explored[5,6], its stability has also been investigated through numerical studies. To analyze the stability, the PIC code calculates its time-evolution of the particle distributions or density profiles of $i^+$ and $e^-$ plasmas initially in the equilibria. The PIC simulation calculates the spatial and temporal evolution of the ion and electron superparticles. As an initial condition of the calculation, $10^6$ ion and $e^-$ superparticles are placed each in the density profile of the equilibrium state. The positions and velocities of the superparticles are then calculated every 10 pico-seconds, which is sufficiently shorter than the cyclotron period of $e^-$ and $i^+$. Figure 1 shows ion velocity field obtained from the distribution of superparticles by using cloud-in-cell method. This indicates that there is azimuthal ion flow in the plasma. This corresponds to the fact that the counter-differential rigid-rotation is driven by a diamagnetic drift. Furthermore, as shown in Figure 2, an examination of the energy in this case reveals that the kinetic energy oscillates in time while the total energy itself grows slowly. These results are discussed.

References

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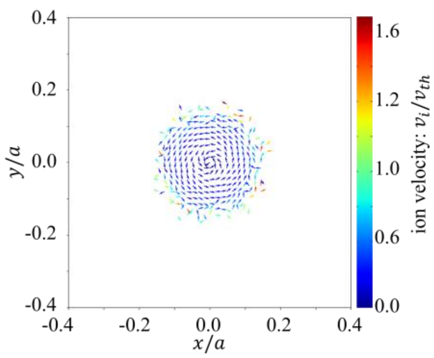


Figure 1: Velocity field of ions 40us after the start of the PIC simulation. B is into the plane of the paper. X and y are normalized by $a = 0.5$, which is a radius of confinement wall. The ion velocity $v_i$ is also normalized by a thermal velocity of ion $v_{th} = 4.9 \times 10^3$ m/s.

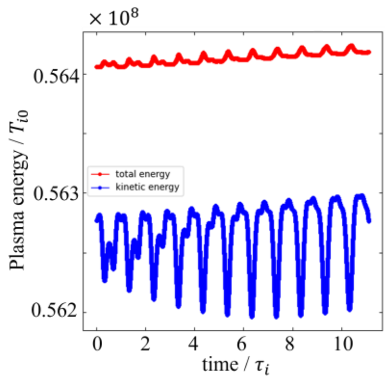


Figure 2: Time-evolution of kinetic and total energy starting from equilibrium states of electrically non-neutral two-fluid plasmas. The energies are normalized by initial uniform temperature of ion plasma $T_{i0} = 2$ eV. The time is normalized by ion cyclotron period of ion $\tau_i = 3.6$ μs.