Applicabilitiy of simple analytical sheath models to RF magnetized sheaths in oblique magnetic fields

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Introduction

- In fusion devices the operation of Ion Cyclotron Radio-Frequency(ICRF) heating systems leads to the formation of RF sheaths at the antenna which are thought to be the cause of numerous unwanted interactions that reduce heating efficiency.
- RF antennas in fusion devices can experience similar RF processes as in magnetized RF capacitive discharges [1].
- The presence of a magnetic field makes the behaviour of such sheaths even more complicated.
- We are investigating how far the magnetic field affects the utility of simple models, that ignore magnetic effects, in describing the RF sheath.

MagPIC Code

- PIC codes model a plasma using computational particles called superparticles which represent a large number of real particles.
- Superparticles move with a finite time step Δt and fields are calculated at the boundaries of finite sized cells, Δx.
- MagPIC is an explicit 1d3v electrostatic PIC code with Monte Carlo collisions - includes the effect of an external magnetic field.
- Simulates a 1D plasma-sheath system in a symmetric parallel plate capacitive discharge with one electrode powered and the other grounded.
- The magnetic field is of constant strength but the angle, θ, is variable relative to the electric field.

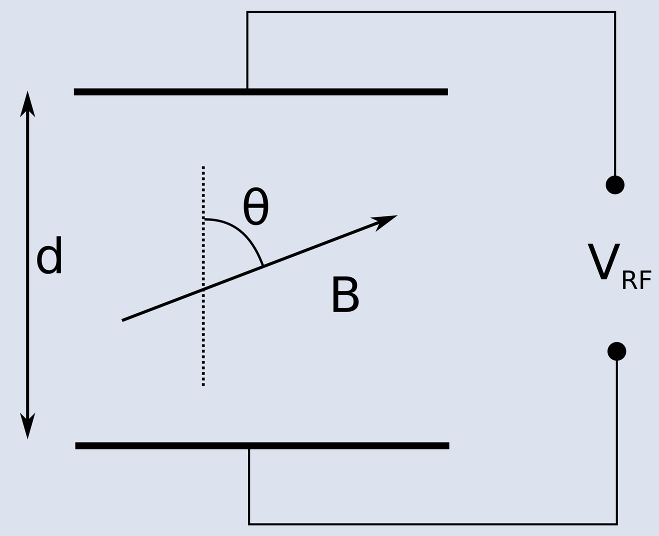

Figure 1: CCP setup

Sheath Models

- Lieberman's[2] sheath model assumes:
  - step model for electrons.
  - ions enter sheath with bohm velocity.
  - collisionless ion motion is the sheath.
  - no e^- current to wall, ion current constant and monoenergetic.
  - does not include magnetic effects.
  - limitation : only considers case of single driving frequency.
- Lieberman expressed the sheath quantities as a function of a single dimensionless parameter H.

$$H = \frac{J_0^2}{e n_0 \pi \epsilon_0 \omega^2 k_B T_e} \quad (1)$$

- Turner and Chabert's[3] simple sheath model simplifies Lieberman's model to include arbitrary waveforms by introducing an ansatz:

$$\bar{n}_e = (1-\xi) n_i \quad (2) \qquad \xi = \frac{\bar{V}}{V_0} \quad (3)$$

- Chodura[4] was the first to study the sheath in the presence of an oblique magnetic field:
  - neglecting collisions and ionisation.
  - postulated existance of a quasi-neutral magnetic presheath(MPS).
  - ions are accelerated to the Bohm velocity in MPS.
  - arrival of the ions at the Bohm velocity signifies the sheath edge.
- In this work we define the sheath edge where the positive space charge in the sheath exactly compensates the negative surface charge, and the field is zero:

$$\int_{electrode}^{sheathedge} n_+(x)dx = -\sigma \quad (4)$$

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Results

- Simulations were run using Helium gas with a driving voltage of 100V with a plate separation of 8cm. The magnetic field strength was kept constant at 12 mT while the angle was varied between 10-85°.

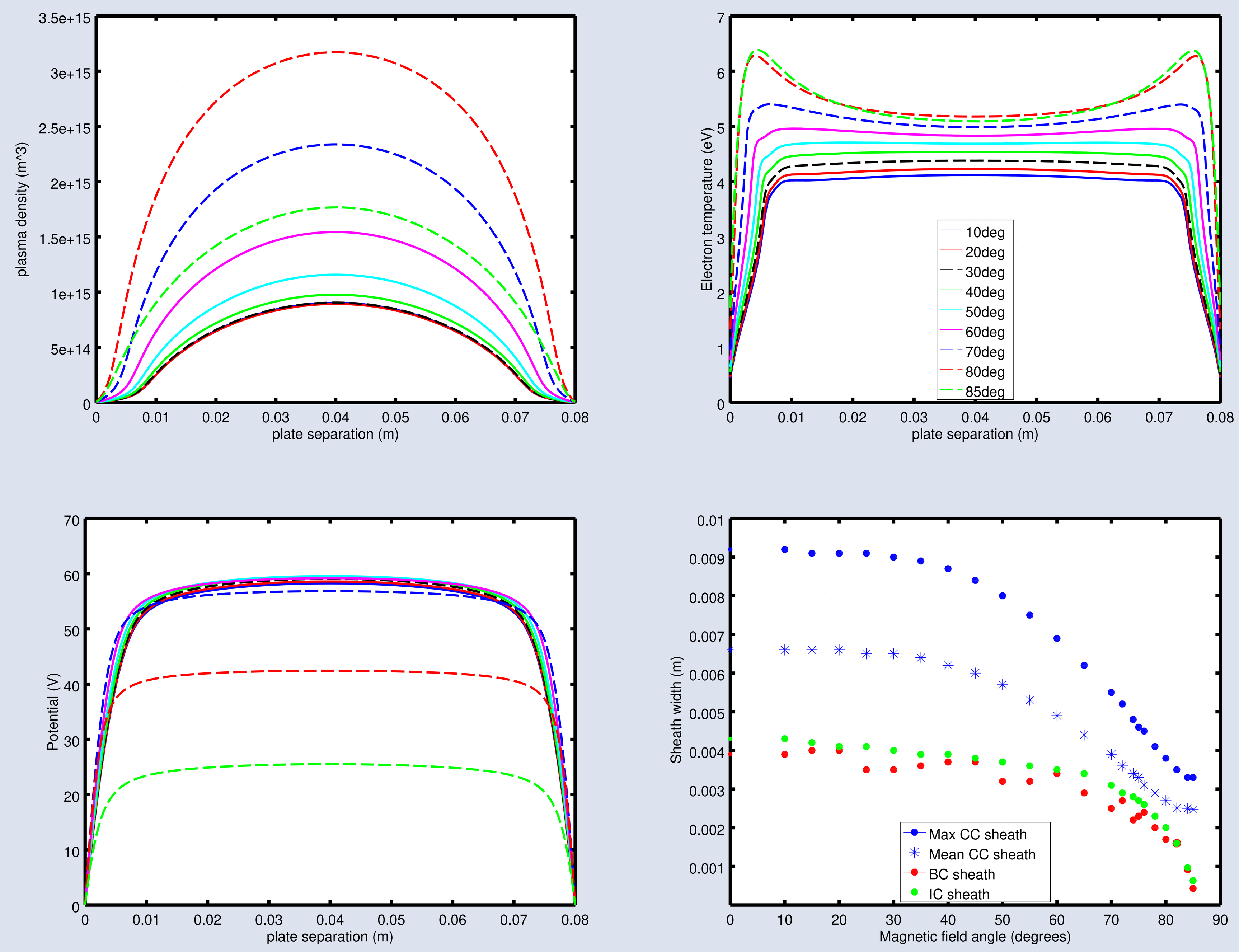

Figure 2: Density, Electron temperature and potential profiles for varying B-field angle. Variation of sheath width, according to 3 different sheath definitions, with B-field angle.

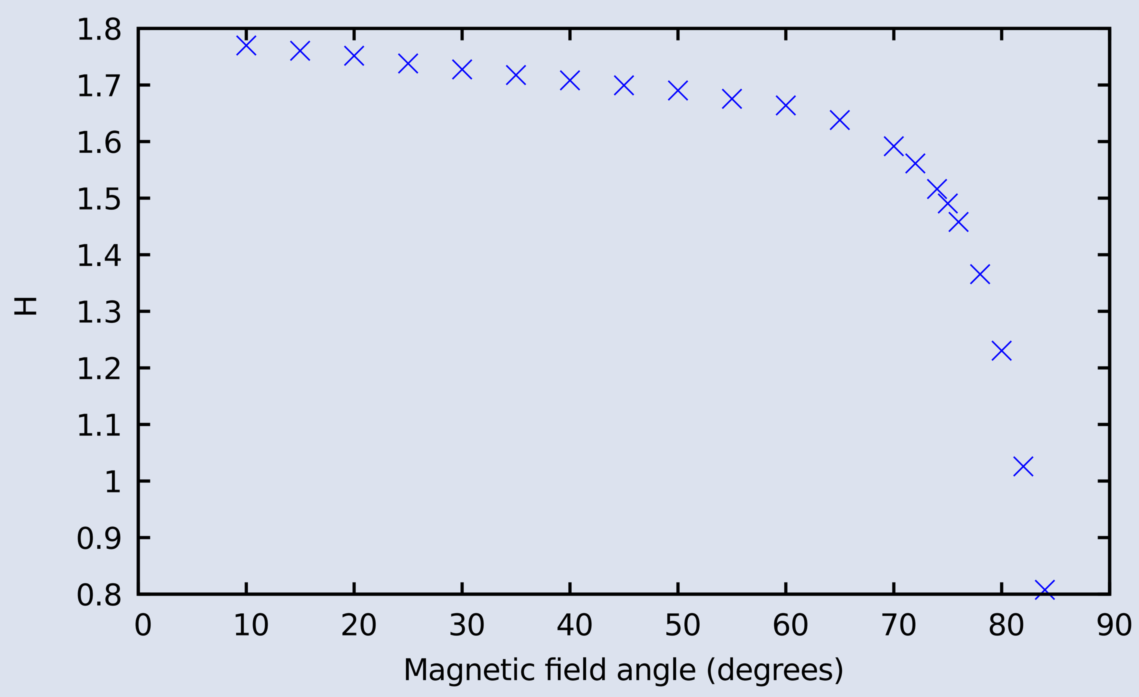

Figure 3: H parameter as a function of the B-field angle.

- Comparison of voltages and current densities from simulation results with model predictions:

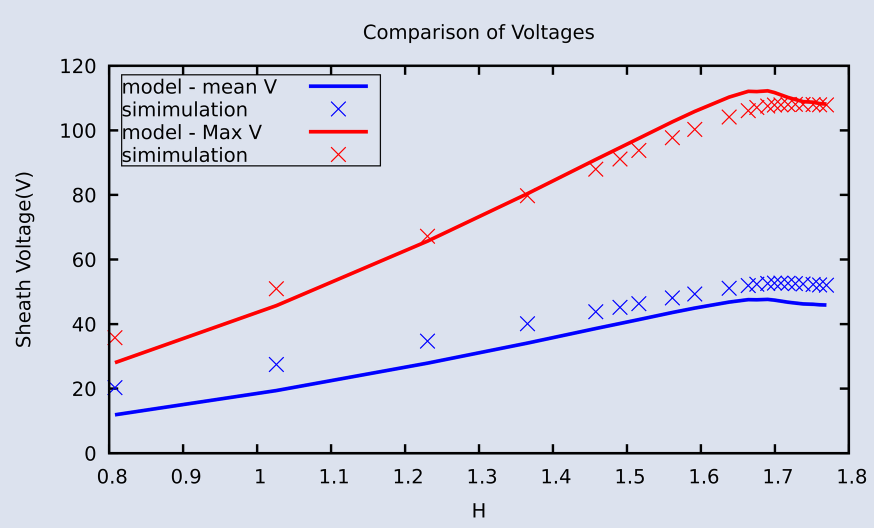

Figure 4: Maximum and minimum sheath voltage as a function of H from simulations(markers) and model predictions(line).

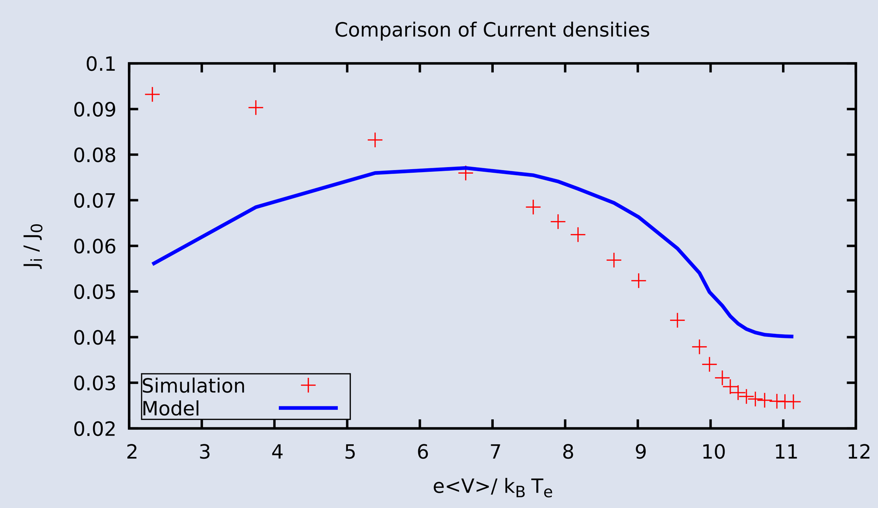

Figure 5: Comparison of the ion current from simulations(markers) with prediction of model predictions(line).

Discussion and Future Work

- Initial investigation suggests that magnetized RF sheaths can be described by simple models that do not include magnetic effects.
- Investigation into the behaviour of different definitions of sheath edge with model predictions.
- Future work will include comparison of oblique cases with experimental results and the extension of MagPIC into 2D.

References

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