CFD modelling of a non-LTE helium discharge using reacting flow and ionic wind approaches

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Abstract: Modelling of a non-local thermodynamic equilibrium (non-LTE) plasma discharge was attempted independently using the reacting flow and ionic wind approaches. The main difference being that the reacting flow simulation considers a reaction mechanism and attempts to model the plasma chemistry, and the ionic wind simulation does not consider a reaction mechanism and only accounts for the transport of the ionic species.

1. Introduction

Non-local thermodynamic equilibrium (non-LTE) plasma flows have been widely applied in various industries. However, there exists a large gap between the fundamental theory and application. CFD modelling can be used to design and predict the performance of non-LTE plasma fluid flow equipment [1]. The modelling on non-LTE plasma is intricate because it involves a description of the charged particle transport coupled with the electromagnetic field equations, the kinetics of excited species (i.e., reaction rates) and the bulk gas flow. Due to this complexity, there is no “standard” model for simulating non-LTE plasma, and the model assumptions and governing equations will depend on the device that is being simulated [2].

The goal of non-LTE modelling is to offer a prediction concerning the physical properties and functionality of a given device. However, even if the model can only predict general trends or aid in the understanding of how a device operates, it remains highly valuable [2].

2. Methods

Initially, a reacting flow non-LTE plasma simulation was modelled as a two-dimensional space model and steady-state time model to reduce the complexity of the calculation and to allow for a converged solution to be obtained. The helium gas is defined as a mixture of electrons, ions and meta-stable components in its three excitation stages. Detailed reaction mechanism information about species and reactions are supplied by complex chemistry definition files that are imported in the Chemkin format.

An attempt was also made to simulate the discharge using an ionic wind approach. Ionic wind is a term that is used to describe an Electro-Hydrodynamic (EHD) flow that occurs due to a corona discharge. When ions are created at the positively charged cathode, coulombic forces are exerted on the ions and create an ionic wind. The ions accelerate towards the negatively charged anode due to Coulomb forces. The ionic wind simulation does not consider a reaction mechanism, and therefore the reactions between species are not considered.

3. Results and Discussion

Figure 1 shows that the maximum calculated electron temperature is similar for both approaches. The electron temperature calculated by the reacting flow model is 1.8% larger than the value calculated by the ionic wind approach. However, the profile of the discharge is different. Figure 1 (b) shows a more sustained discharge shape especially at the cathode tip, with a value of approximately 1.4 eV calculated near the tip of the cathode.

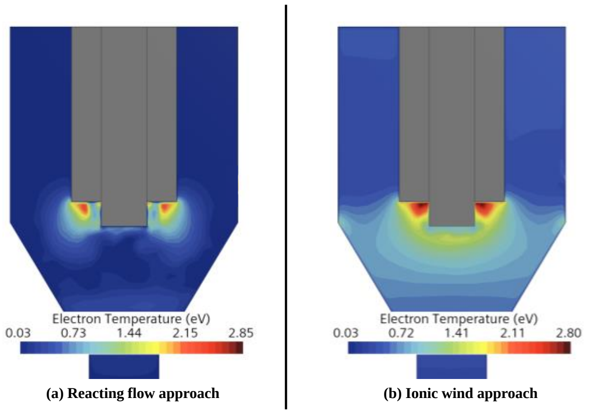

Fig. 1. A comparison of the electron temperature calculated using (a) the reacting flow approach, and (b) the ionic wind approach.

4. Conclusion

The results have shown that a commercial CFD code can be used to obtain meaningful results of a non-LTE discharge. Useful information can be extracted from the simulation results. These results can be used to optimise the designs of high pressure, low-current plasma reactors.

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References

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