S6-02

Fundamental - Numerical:
Advances and Challenges in Computational Fluid Dynamics of Atmospheric Pressure Plasma

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1. Introduction

Atmospheric pressure plasmas (APPs) are found in applications ranging from materials processing and chemical synthesis to water treatment and medicine. APPs span from low-power non-thermal to high-power thermal discharges. The advances and challenges of Computational Fluid Dynamics (CFD) of APP flows can be broadly characterized in terms of model fidelity and numerical accuracy [1]. Fidelity relates to the level of phenomena described by the model, whereas accuracy to the precision of the numerical solution of the model. Representative fidelity challenges are nonequilibrium electron and particle kinetics, plasma-surface and plasma-radiation interaction, and multiphase plasmas, whereas numerical accuracy challenges are the resolution of instabilities, pattern formation, plasma-gas interaction, and turbulence.

2. Example: Arc plasma flows

Industrial applications of arc plasmas are prone to diverse types of kinetic and dissipative nonequilibrium [2]. CFD simulations of arc plasma flows exemplify fidelity and accuracy challenges. Representative simulations of arc plasmas are shown in Fig. 1, i.e., a plasma torch and an arc in crossflow.

3. Model fidelity and numerical accuracy

The needs for greater fidelity and accuracy can be limitless. This can be appreciated by considering, for example, the interaction of turbulent plasma flow with a solid substrate, particles, or with a gas or liquid environment. In contrast to these needs, computational resources are bounded. This challenge is schematically depicted in Fig. 2. Given fixed resources, such as CPU-hours, and since the cost of simulations depends on the total number of unknowns (*model variables*)x(*discretization nodes*), the level of fidelity and accuracy of a particular simulation are inter-dependent. Better *numerical simulations* involve solving a given model with increased accuracy (e.g., improved resolution of gradients), whereas *better models* generally involve a greater number of independent variables (e.g., multiple temperatures, more chemical species). The ideal advancement of CFD models of APP flows would allow more efficient utilization of computational resources to concurrently improve both, numerical accuracy and model fidelity.

4. Conclusions

The advances and challenges of CFD of APP flows can be characterized in terms of model fidelity and numerical accuracy. Progress towards predictive CFD simulation of APP flows requires concurrent progress of both, fidelity and accuracy.

Acknowledgements

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References

[1] J.P. Trelles, Plasma Sources Sci. Technol., 27, 093001 (2018).

[2] J.P. Trelles, Plasma Chem. Plasma Process., **40**(3), 727 (2019).

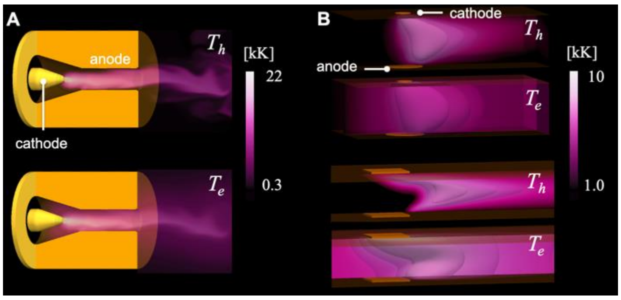

Fig. 1 Arc plasma flow simulations: (A) non-transferred arc plasma torch, (B) arc in crossflow.

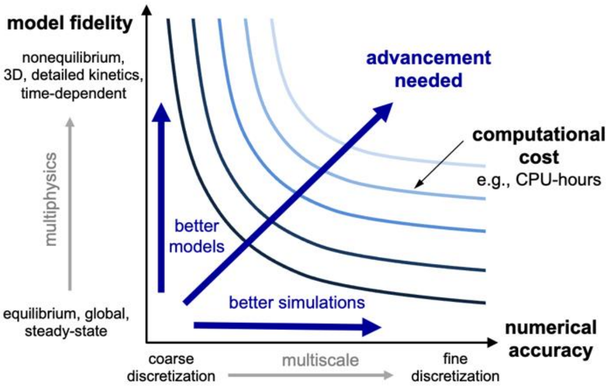

Fig. 2 Model fidelity and numerical simulation in the computational modeling of atmospheric pressure plasma.