Enhancement of Numerical Solver for Modeling Supersonic Plasma Jet Interactions with Electrodes in Cutting Torch Applications

CFD Insights services

August 2023

Objective

As part of the investigation into supersonic plasma jets utilized with plasma cutting torches, a novel numerical solver based on a Godunov-type finite volume scheme was developed in the client company. This solver enhanced the accuracy of modeling shock waves within supersonic plasma flows. A critical aspect in the advancement of torches for cutting and welding involved understanding the interaction between the highly energized plasma jet and the surrounding geometry, particularly the electrode. The primary objective of this project was to extend the capabilities of the solver to incorporate the coupled phenomena between the plasma and the electrode. Specifically, the focus was on accurately capturing the thermal and electrical potential exchanges between the plasma and the electrode. Furthermore, the developed code underwent validation against experimental data to ensure its reliability and accuracy in simulating the complex interactions between the plasma jet and the surrounding components.

Methodology

For confidentiality reasons, this report omits specific details regarding methodologies, numerical schemes, and code development frameworks.
However, a general overview of the geometry is provided for clarity. More precisely, Figure 1 showcases the complete geometry, encompassing both the electrode and the plasma channel. Simulating the interaction between the electrode and the plasma concerning temperature and electrical field is vital for optimizing performance, ensuring electrode durability, maintaining safety, controlling processes, and understanding material behavior. By comprehensively assessing these interactions, engineers can enhance the efficiency, precision, and quality of cutting or welding processes while also mitigating safety risks and extending the lifespan of equipment.

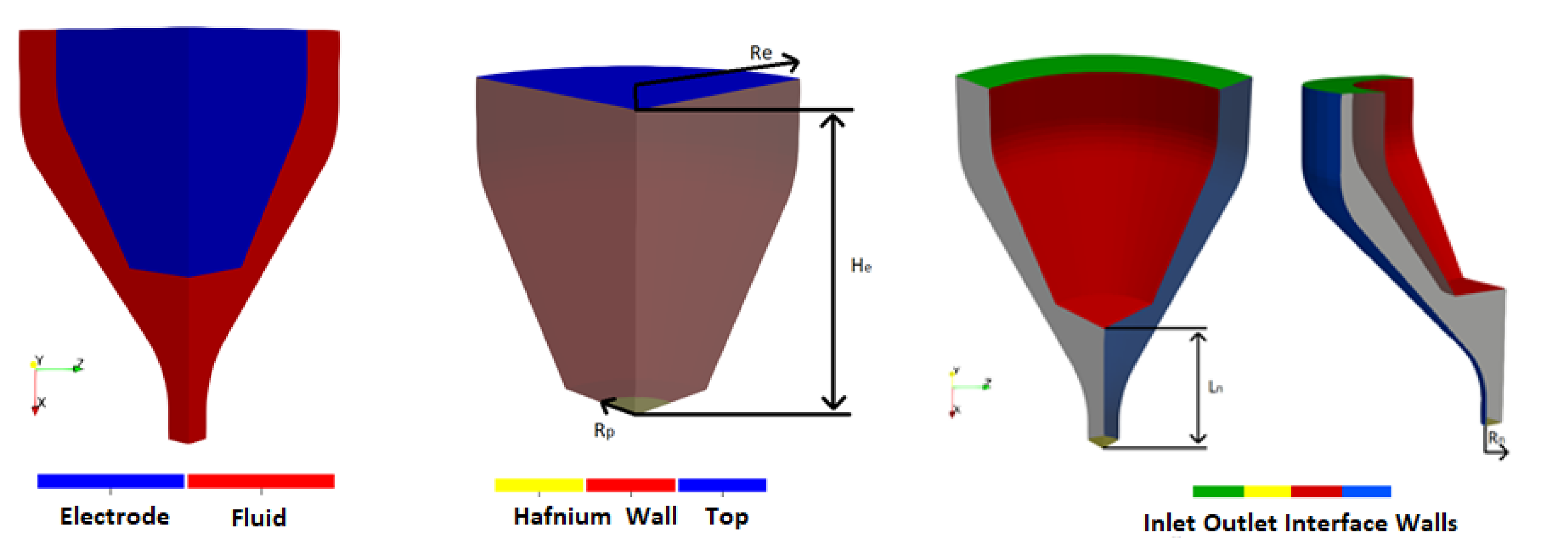

Figure 1:Examined geometry

Results

The evaluation of the code's accuracy was based on the comparison of the simulated data generated by the novel code against the experimental temperature measurements provided by the client. While the code comprehensively addresses both thermal and electrical load exchange phenomena, the validation efforts outlined in this report are specifically focused on temperature validation. Figure 3 illustrates a comparison of the temperature along the radial direction at the top of the electrode, whereas Figure 4 emphasizes the temperature distribution along the axial direction of the electrode.
The graphs indicate that the code was able to generate values sufficiently close to the recorded data. Overall, an average error of less than 2.2% was observed for the radial distribution, while for the axial distribution, the error averaged at 1.1%.

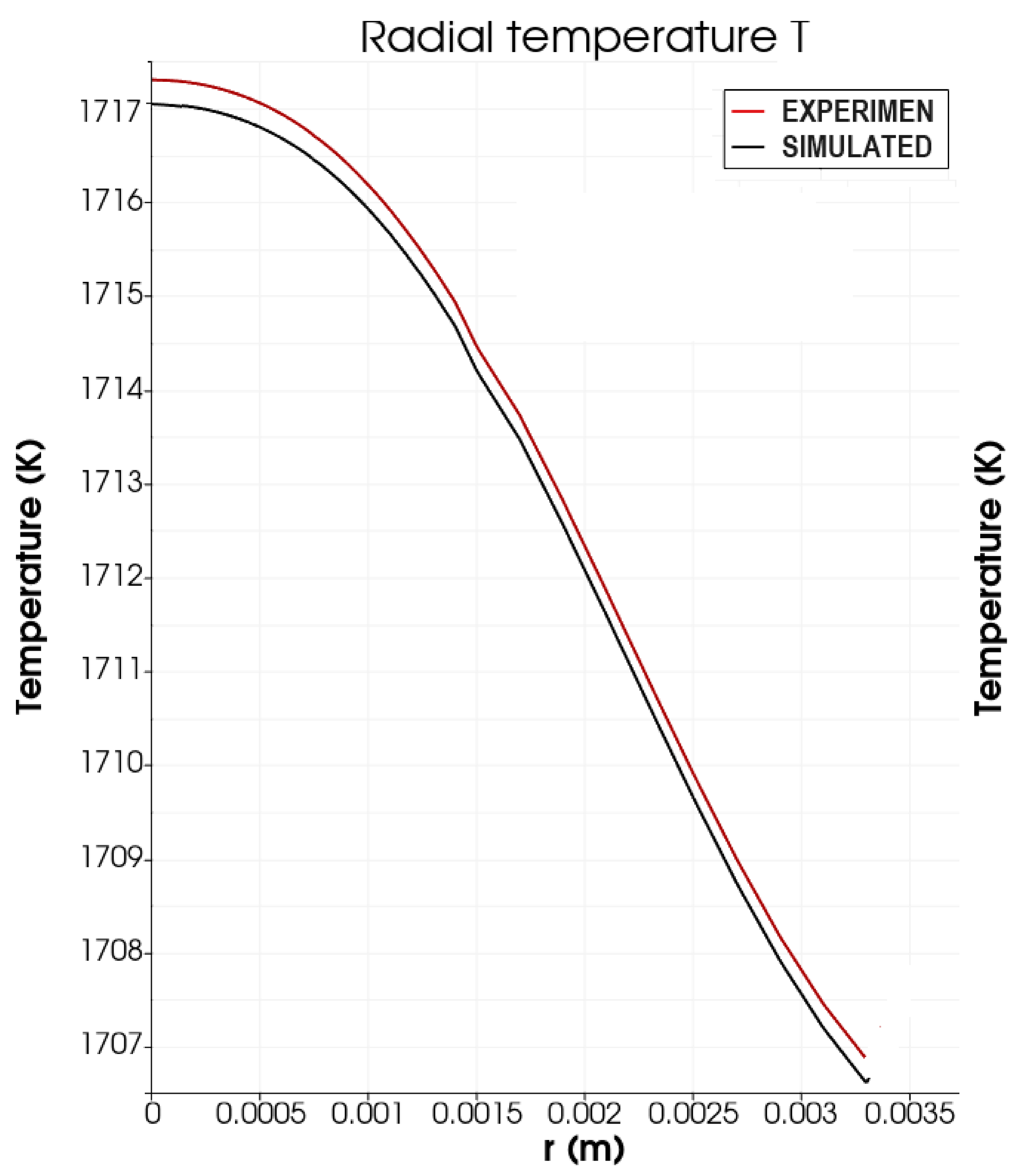

Figure 2:Radial temperature comparison.

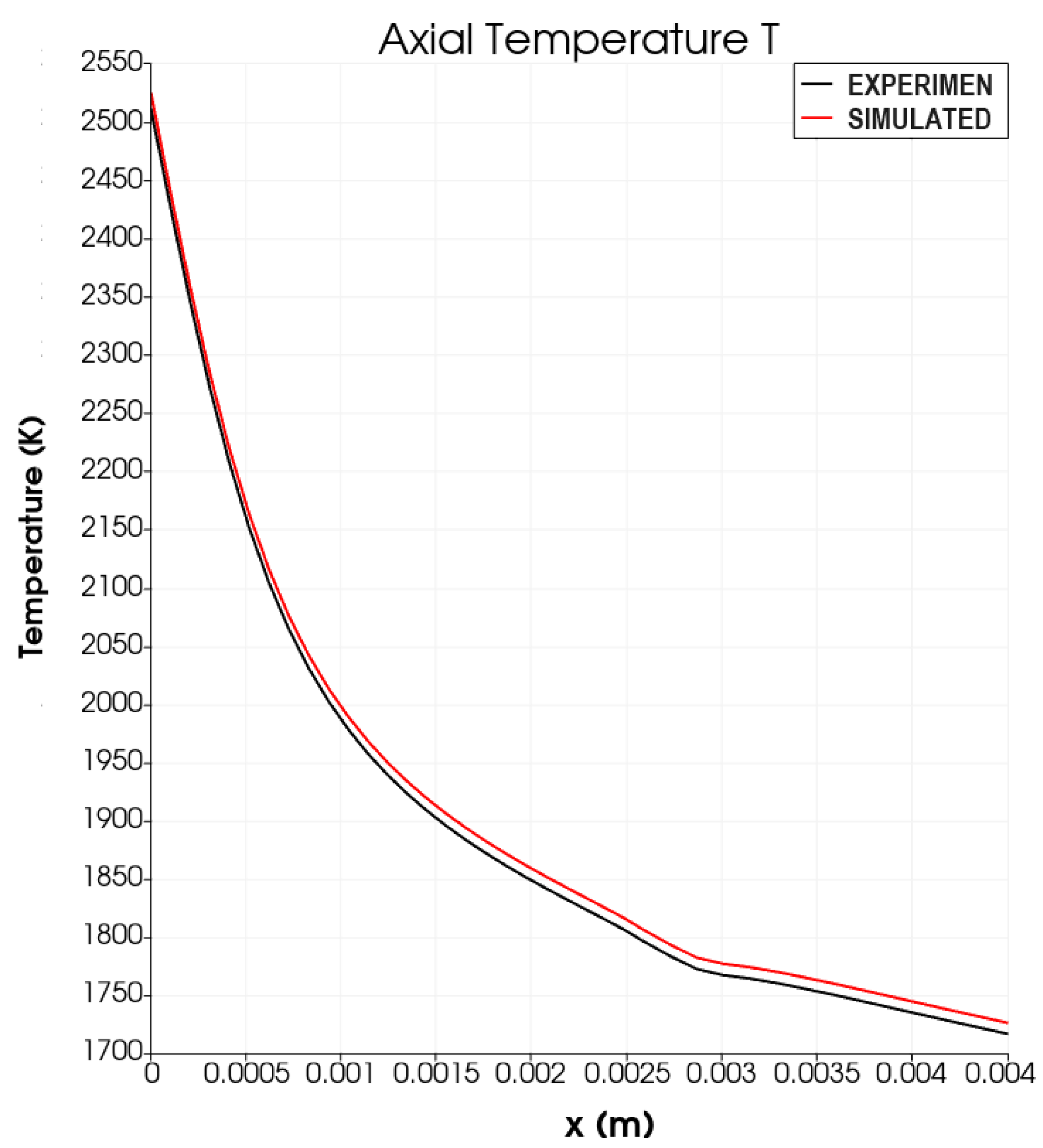

Figure 3:Axial temperature comparison.

Conclusion

The project aimed to develop and refine a code simulating the complex interactions between plasma jets and electrodes in cutting torch applications. The results indicate that the developed code performed satisfactorily, with numerous validation cases yielding positive outcomes. As a result, efforts were subsequently directed towards optimization procedures.