Quantitative Schlieren imaging and Pitot tube velocimetry coupled to a numerical model to investigate the flow field of an AC-driven SDBD

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1. Introduction

The present work is devoted to the investigation of the flow field induced by an AC-driven surface dielectric barrier discharge (SDBD) in ambient atmospheric air. The gas density and temperature are evaluated by means of time-resolved schlieren imaging, while the gas velocity is measured using a Pitot-like arrangement. The experimental data are used to calibrate a numerical model, allowing for the assessment of the electrohydrodynamic (EHD) force.

2. Diagnostics and Numerical Model

The AC-driven SDBD reactor is presented in Fig. 1a (details in [1]). The gas flow field patterns are recorded with a schlieren system based on a Z-type configuration (power LED; parabolic mirrors; Foucault knife) and equipped with a high-speed camera. The side-on resulting patterns are transformed with inverse Abel method and further treated as in [2], allowing for the determination of the space- and time-resolved gas density and temperature. The average gas velocity is measured by means of a Pitot-like system, consisting of a dynamic pressure digital anemometer, two capillary tubes (inner diam. 800 μm), and a 3-axis digitally controlled translation stage (resolution 5 μm in all axes). The average velocity values feed a numerical model [3], allowing for its calibration and eventually the estimation of the EHD force spatial distribution. Briefly, the model interconnects three modules which treat different physical effects occurring at different timescales. Namely, discharge dynamics, ion transportation, and fluid motion.

3. Results and Conclusions

Fig.1b presents a typical flow field pattern, after inverse Abel transformation, unveiling a laminar region up to about 40 mm downstream of the driven electrode edge. The color map provides the axial and radial values of both the normalized gas density (min. 0.9) and temperature (max. 329 K), within this laminar region, as they are calculated according to [2]. At the same time, Fig.1c demonstrates the corresponding developed velocity (max. 6.09 m/s), while Fig.1d shows the numerically determined EHD force (max. 32.72 kN/m^3). These results underline the worth of the present experimental–numerical combined tools to fundamental gas flow field studies (both in time and space domain).

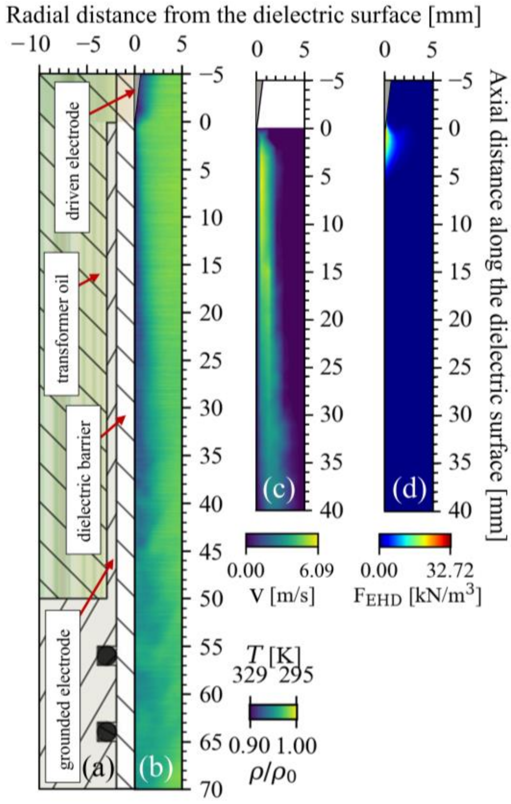

Fig. 1: (a) Longitudinal section of the cylindrical SDBD reactor. (b) Flow field pattern with the calculated gas density and temperature. (c) Measured velocity field. (d) Numerically determined EHD force. 20 kV$_{pp}$; 10 kHz; 20 min of reactor pre-operation for ensuring stabilization.

References

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Acknowledgements

Work partially funded by Horizon-EIC-2023 Pathfinder Open (GA 101129853) and UKRI (GA 10106237).