Validation of Computational Fluid Dynamic Simulations with Background Oriented Schlieren Technique

Alexander Haack; Sebastian Klopotski; Walter Wissdorf; Thorsten Benter

Introduction

CFD-Simulation: For the reduced model, a simplified, rotationally symmetric model of the schlieren was used. Boundary conditions: T_Neb = 553 K, v_Neb = 10 parabolic, v_{near} = 2.8 m/s, p_{out} = 1 atm. Fluid properties: standard air

Interpolation: Defect magnitude over the irregular mesh Output: regular 3D-array of fluid density (Fig. 3)

Calculation of the refractive index: Refractive index is in each element of the array from the density ρ as determined with the Gladstone-Dale equation:

\[ n = \sqrt{\frac{\rho_2}{\rho_1}} \]  

with C = 0.233 m^3/kg Gladstone-Dale constant (4)

Output: regular 3D-array of the refractive index distribution

Light deflection: As light travels through a continuous medium with a spatial gradient of refractive index, it is deflected. If the gradient is small, the deflection angle is given by the integration along the line-of-sight (projection along z-axis).

Validation: On the basis of the numerical calculation of the deflection angle (in a 3D-array, with elements c_{ij,kl} where k indicates the bin of projections) a demonstration (de-convolution of the integral is used):

Conclusion

1. Optimised experimental setup and visualization may give new insights into the highly dynamic processes in atmospheric pressure ion sources.
2. The combination of simulated Schlieren images and the BOS model is demonstrated to be a great tool for the validation of CFD simulations and the dependences on various physical parameters.
3. The great advantage of this setup is the straightforward implementation and simple operation of the experiments.

Literature


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