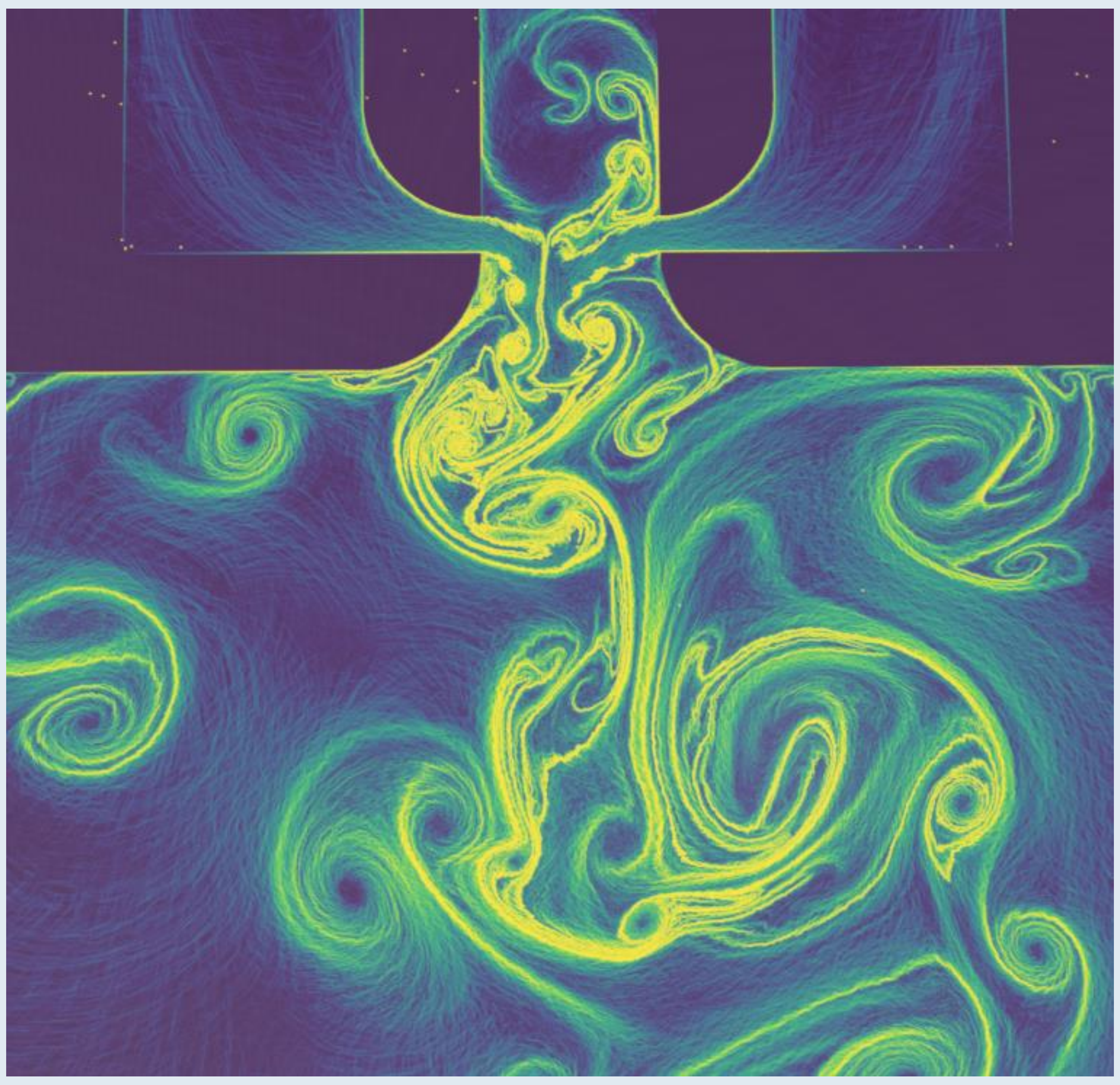

Towards Data Driven Design of Flow Blurring Atomizer

This study showcases the synergy between machine learning, experiments and CFD, and how it can be utilized to shed light on the momentum transfer mechanism that underpins the atomization process.

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Abstract

Liquid atomization relies on various forces that disrupt the liquid's surface. In flow-blurring (FB) atomization, turbulent structures are induced within the liquid channel to achieve this effect. This study aims to establish a database of transient gas-phase coherent structures under different operational conditions and nozzle designs, shedding light on the underlying momentum transfer mechanism.

Data collected is processed using machine learning algorithms to explore the optimal sensor configuration for capturing informative signals and to determine the feasibility of estimating surface shear through simple pressure measurements in a real setup.

The analysis demonstrates that it is not only possible to characterize flow regime shifts with a single pressure sensor but also to estimate the surface shear acting upon it.

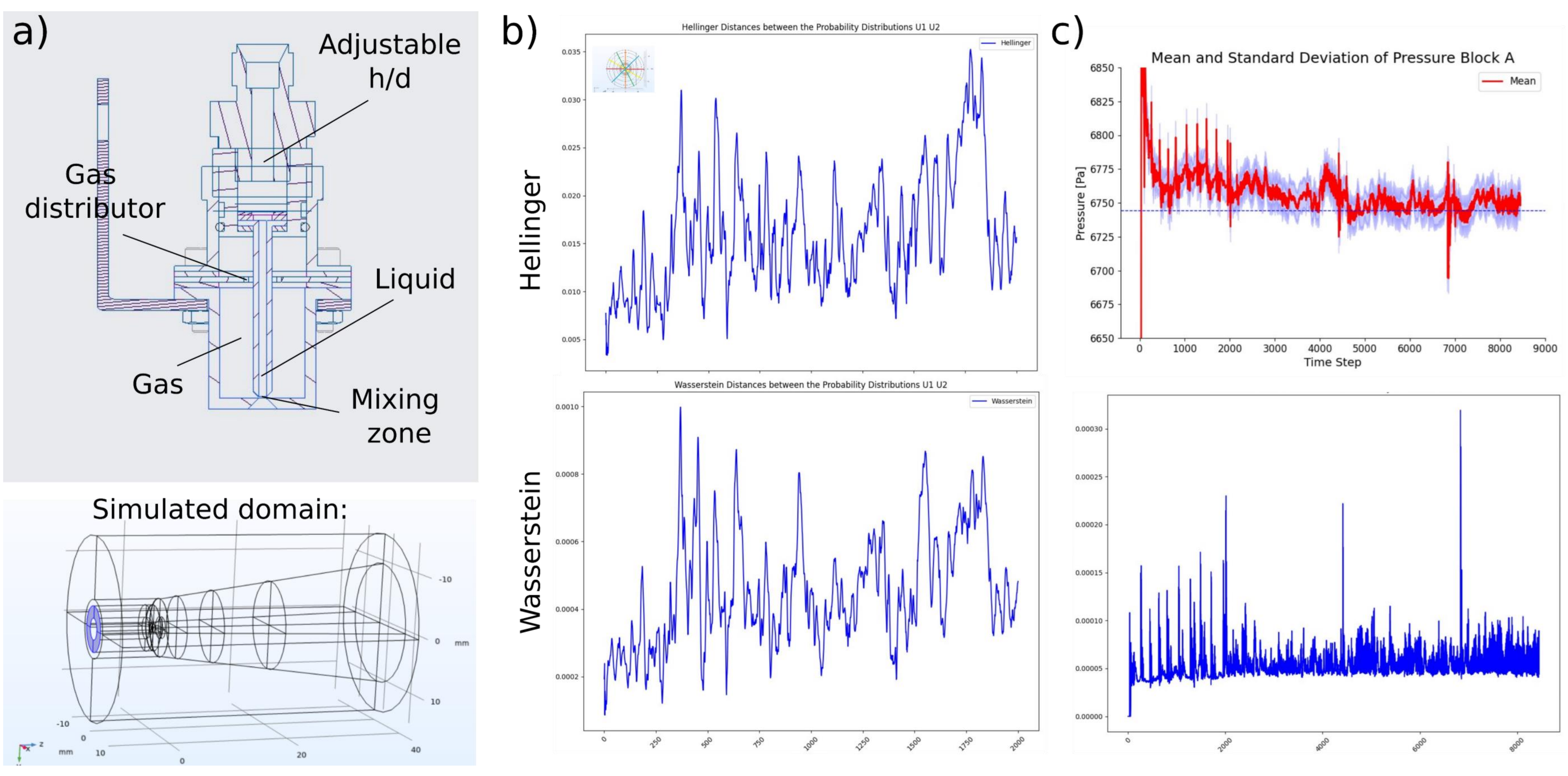

FIGURE 1. a)Nozzle geometry and the solution domain, b)Similarity analysis between sampling planes via Hellinger and Wasserstein distances as a function of time, c)Comparison between virtual pressure probe readings and the corresponding Wasserstein distance as a function of time.

Methodology

Our previous analysis showed that the FB atomization process exhibits a cyclic two phase flow behavior [1]. To facilitate the parametric study, the transient gas phase flow at different phases of the atomization process is modelled via Large Eddy Simulation (LES).

Flow asymmetry and the 3D nature of the flow structures were by calculating Hellinger and Wasserstein distances between velocity and pressure distributions, along with using recurrence plots. Subsequently, we used the collected simulation data to train multiple machine learning-based predictors, including LASSO, Random Forest (RF), Support Vector Machines (SVM), and Artificial Neural Network (ANN), to evaluate the informativeness of virtual pressure probes.

Results

Analysis of similarity between different planes suggests that the pressure field exhibits symmetry, implying that even a single sampling probe may provide sufficient information for assessing the flow regime. Additionally, the examination of shear data indicates that not only can flow regime shifts be characterized with a single pressure sensor, but surface shear can also be estimated.

The findings have practical implications for optimizing atomizers in a variety of applications, including combustion systems and spray coating processes. Moreover, the integration of machine learning techniques and simulation tools opens up new avenues for enhancing the efficiency of atomization simulations and guiding future experimental investigations.

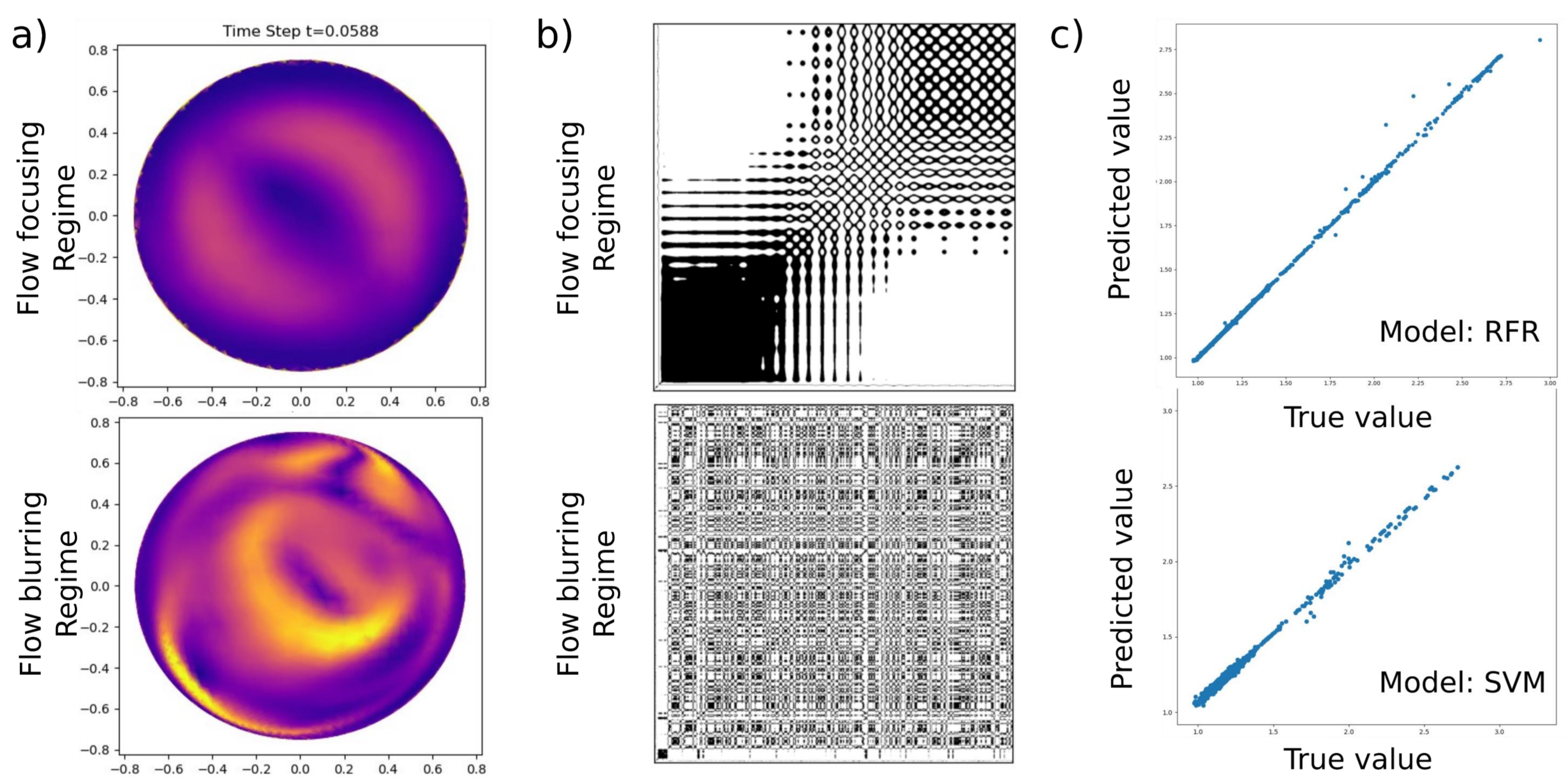

FIGURE 2. a) Comparison of shear distribution at flow focusing and flow blurring regimes for the same geometry, b) Recurrence plots for the mean shear acting on liquid surface for flow focusing and blurring regimes, c) Comparison between the CFD calculations and the predictions of ML models based on pressure probe data for the mean shear.

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[1]. C. Ates, C. Gundogdu, M. Okraschevski, N. Bürkle, R. Koch, H.-J. Bauer., Characterization of Flow-Blurring Atomization with Smoothed Particle Hydrodynamics (SPH), International Journal of Multiphase Flow, Vol. 164, 104442, 2023.

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