Stress fields and morphological evolution in multiphase flow and soft matter: insights from high-speed imaging and AI

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Abstract

Understanding the complex interplay between stress fields and morphological evolution in multi-phase flows and soft matter is crucial for both fundamental fluid mechanics and practical applications. In this talk, we present recent advances in high-speed imaging and explainable artificial intelligence (AI) to uncover the underlying physics of droplet impact, cavitation-driven microjets, and bubble-induced stress distributions. Using cutting-edge visualization techniques such as background-oriented schlieren (BOS) tomography and photoelastic stress analysis, we reveal how local stress fields govern droplet splashing, jet penetration, and cavitation collapse dynamics [1,2]. Our findings indicate a stress-driven crossover in force scaling for droplet impact on elastic substrates [3] and optimal standoff distances for microjets penetrating soft materials [4]. Furthermore, AI-based feature extraction enables a deeper interpretation of high-dimensional flow data, allowing us to predict and classify morphological transitions with unprecedented accuracy [5]. These insights have broad implications, ranging from biomedical applications such as needle-free injections [4] to industrial processes involving multiphase flows. This study highlights the synergy between experimental fluid mechanics and AI-driven analysis, opening new avenues for understanding and controlling multi-phase phenomena.

Keywords: Multiphase flow, Stress field, High-speed image, AI-based analysis, Drop impact

Figure 1.(a) Stress field in soft material induced by droplet impact [3] and (b) AI-based analysis of the impact [5]

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