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Comparative Study of Lagrangian POD and DMD for the Analysis of 3D Bubble Rise Characteristics

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The reliability of traditional data-driven techniques has often been challenged by complex transient flow phenomena[1]. Using Lagrangian trajectories with Dynamic Mode Decomposition (DMD) can address challenges such as the translational issue in a 2D rising bubble[2]. The present study extends and compares this approach by investigating the applicability of Proper Orthogonal Decomposition (POD) and DMD in the study of rise characteristics of a 3D deforming bubble following a zigzag path with a previously validated DNS simulation obtained from a Conservative Diffuse Interface (CDI) method[3]. The results show that Lagrangian POD (L-POD) can efficiently extract the dynamics using as few as 10 modes, whereas Lagrangian DMD (L-DMD) requires over 100 modes. Thus, considering Lagrangian trajectories, L-POD is a more efficient tool for reduced-order modeling in this application. As shown in Figure 1, the work's outcome highlights L-POD's potential in obtaining the rise characteristics, including terminal velocity, rise trajectory, and the bubble interface, during the entire rising process, comprising the rectilinear, transition, and oscillatory stages. Using data-driven techniques has the potential to extend our understanding of bubble deformation by focusing on the most dominant modes, paving the way for future advancements in capturing complex bubble dynamics.

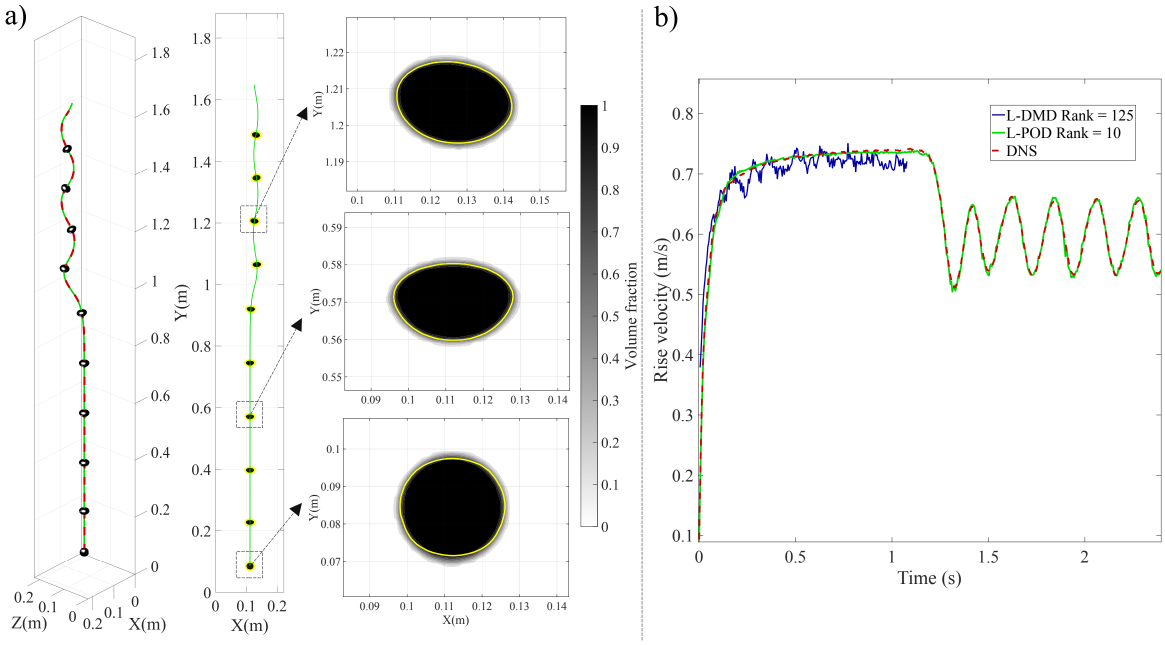

Figure 1: Reconstruction of a) rise trajectory, the interface (rendered in yellow), and b) the rise velocity of a bubble.

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[2] Y. Yin et al. In: *Industrial and Engineering Chemistry Research* 62 (2023), p. 15255.
[3] Sanjid S. Chirammel et al. In: *Proceedings of ICNMMF-5*. Reykjavik, Iceland, 2024.