Meshless POD for Sloshing Modes identification in Non-Canonical Tank Geometries

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Abstract. In the context of future aviation design, conformal fuel tanks are increasingly adopted to reduce aerodynamic drag and enhance aircraft performance. Sloshing dynamics in such geometries pose unique challenges that can impede the application of traditional reduced-order modeling techniques. Pendulum-like models, while appealing for their simplicity and computational efficiency, often fail to capture the multi-modal behavior and complex free-surface deformations inherent to non-standard tank geometries. Similarly, classical modal Galerkin expansions typically rely on simplified potential flow assumptions and analytically derived eigenfunctions, which become increasingly difficult to derive in the presence of geometric irregularities. As a result, both approaches can suffer from inaccuracies in predicting the sloshing behavior in conformal tank geometries. In this work, we propose an alternative strategy relying high-fidelity numerical data acquired through meshless simulations to identify the sloshing modes in non-canonical shapes. Using meshless Proper Orthogonal Decomposition (POD), we extract a set of flow patterns that accurately reflect the sloshing dynamics. This decomposition is used to construct a reliable reduced-order model allowing to reconstruct the essential liquid flow dynamics. This ROM construction methodology offers a promising pathway toward robust sloshing predictions suitable for real-time flow control or tank shape design for future aeronautical applications.