147

A Parametric Study of Bubble Dynamics Under Magnetohydrodynamic Effects: Control of Cavitation and Sonoluminescence

Author: Matheus ARAUJO AGUILAR[1]

Co-author: Francisco Ricardo Cunha [1]

[1] *University of Brasilia*

Bubble dynamics in magnetic fluids and electrically conducting liquids plays a key role in cavitation control, gas evolution, plasma–liquid interactions, in the phenomenon of sonoluminescence and heat and mass transfer. Building upon Rayleigh–Plesset-type models[1] , unified bubble dynamics formulations [2], and prior studies on magnetic fluids and magnetohydrodynamics (MHD) [3–8], we develop a theoretical reduced-order model for a spherical gas bubble subject to acoustic forcing and magnetic stresses.In the ideal-induction MHD limit, the magnetic contribution is expressed as a compact nonlocal functional enabling a separation between bubble kinematics and field geometry. Two closure strategies are investigated: (i) an interface-only model characterized by a decay exponent alpha, and (ii) a PDE-lite closure based on finite-energy advected envelopes Phi(s). The interface-only formulation reveals a sign-dependent stiffness shift: alpha < 1 leads to magnetic stiffening, whereas alpha > 1 results in magnetic softening. Frequency and amplitude sweeps are evaluated using post-transient cycle-median extrema. Cavitation mitigation is quantified through the minimum bubble radius and a centered liquid-side wall-pressure proxy, while sonoluminescence enhancement is assessed via a polytropic gas-temperature proxy. The results indicate that magnetic stiffening detunes resonance-like amplification, increases the minimum radius, and attenuates tensile pressure excursions. In contrast, magnetic softening amplifies compression and heating bands, raising the temperature proxy but also producing more negative wall-pressure minima.A local calibration procedure maps the PDE-lite functional onto an equivalent exponent α_{eq}, reproducing representative post-transient trajectories with sub-percent discrepancies. Overall, the proposed model provides a compact parametric framework for identifying magnetic conditions that either suppress bubble collapse or enhance compression in magnetized multiphase flows, complementing recent studies on cavitation erosion and plasma–liquid transport [9].

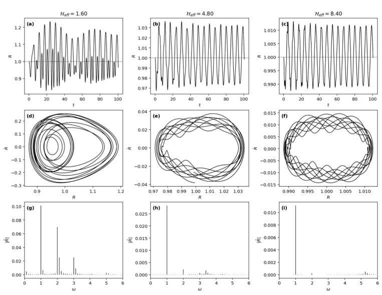

Figure 1: Post-transient bubble dynamics for the interface-only magnetic closure in the stiffening regime. Panels (a)–(c): radius time series $R(t)$. Panels (d)–(f): phase portraits $(R, \dot{R})$. Panels (g)–(i): Fourier amplitude spectra $|\hat{R}|$ versus ω. The three columns correspond to $\mathcal{H}_{eff} = 1.60$, 4.80, and 8.40, respectively. Parameters: $\alpha = 0.7$, $Re = 90.0$, $We = 30.0$, $\varepsilon = 0.3$, $\omega = 1.0$, and $\kappa = 1.2$.

References

[1]M.S. Plesset and A. Prosperetti, Annu. Rev. Fluid Mech.9, 145–185 (1977).
[2] A.-M. Zhang et al., Phys. Fluids 35, 033323 (2023).
[3] R.E. Rosensweig, Ferrohydrodynamics, Cambridge Univ. Press (1985).
[4] S. Malvar et al., J. Eng. Math. 108, 143–170 (2018).
[5] Y. Huang et al., Phys. Fluids 33, 097110 (2021).
[6] Y. Feng et al., Phys. Fluids 36, 042122 (2024).
[7] M.C. Cockerill et al., Phys. Fluids 37, 042116 (2025).
[8] S. Pignatiello et al., Fusion Eng. Des. 219, 115215 (2025).
[9] Z. Zhao et al., J. Fluid Mech. 1015, A33 (2025).

Type:

Poster