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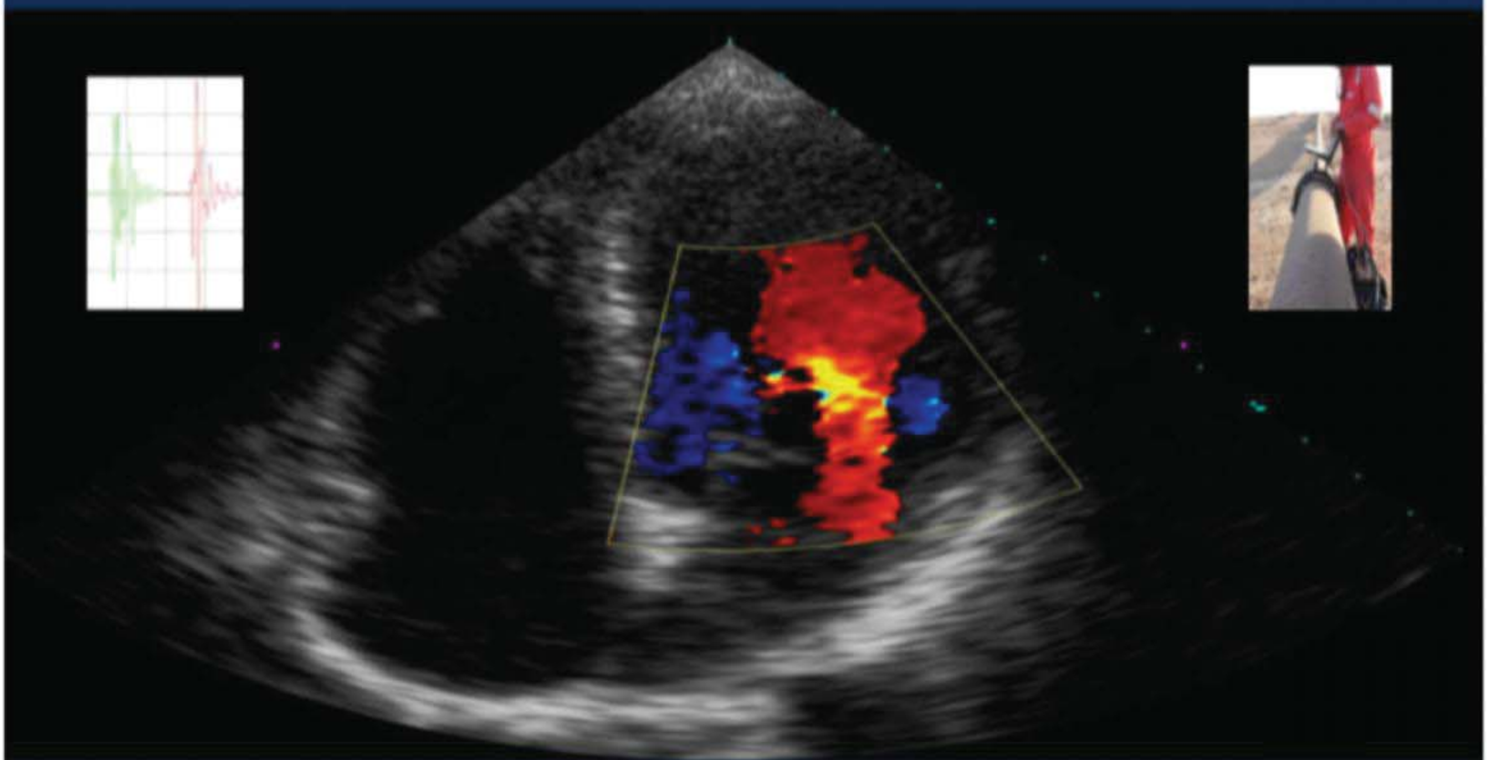

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O 23B — Numerical study of ultrasound induced non-linear shape and size bubbleoscillations in viscoelastic media

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Abstract

The theoretical study of forced bubble oscillations is motivated by the importance of cavitation bubbles and oscillating encapsulated microbubbles (i.e. contrast agents) in medical sciences. In more details, theoretical studies on bubble dynamics addressing the sound-bubble interaction phenomenon provide the basis for understanding the dynamics of contrast agent microbubbles used in medical diagnosis and of non-linearly oscillating cavitation bubbles in the case of high-intensity ultrasound therapy. Moreover, the inclusion of viscoelasticity is of vital importance for an accurate theoretical analysis since most biological tissues and fluids exhibit non-Newtonian behavior [1].

In this work, we study numerically non-linear bubble oscillations driven by an acoustic pressure with the bubble being immersed in a non-Newtonian liquid with its viscoelasticity described by an advanced model with non-linear viscoelasticity (e.g. Phan-Thien–Tanner model of exponential form) [2]. The proposed computational approach [3] is general without ad hoc simplifications and assumptions, does not rely on the solution of the simplified Rayleigh–Plesset equation used in previous studies, which limits the study to only spherically symmetric bubbles, and provides coupled solutions for the velocity, stress fields and bubble interface. The developed numerical scheme is based on a Garlekin finite element (FE) discretization of the Navier–Stokes flow equations coupled with a robust quasi-elliptic grid generation technique (based on conformal mapping methods). We present solutions for non-spherical bubbles, with asphericity being addressed by means of Legendre polynomials or associated Legendre functions. In Figure 1, a typical mesh for the fluid domain around the bubble generated during the simulation following the bubble oscillatory behavior for a non-spherical bubble is shown. Extensive numerical calculations demonstrate that in general increasing elasticity and/or viscosity of the surrounding liquid tend to stabilize the shape anisotropy of an initially non-spherical bubble and that the amplitude of bubble oscillations drastically increases as liquid elasticity increases or as liquid viscosity decreases. The liquid rheological parameters regarded are in accordance with reported values for biological liquids and the amplitude/frequency of the imposed pressure lie in the regime of operational conditions in medical ultrasound diagnosis.

References

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Figures

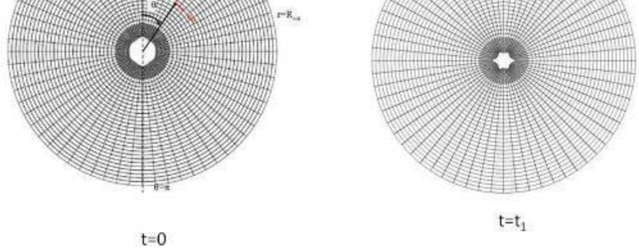

Figure 1 Mesh generated during the simulation for the liquid domain around the bubble a) initial mesh for a non-spherical bubble described by: 0 ( ) b b0 b0 6 R (θ, t = 0) = R + 0.1R P cosθ , b) at bubble minimum