Acoustic-Structure Interaction Modeling of Piezoelectric Transducer in Fluid Medium

Acosta, V. M.[1], Riera, E.[1], Rodriguez, G.[1], Pinto, A.[1], Cardoni, A.[2], Gallego-Juárez,J.A.[1]

[1]Power Ultrasonics Group, CSIC, Serrano, Madrid, Spain

[2]Pusonics, Arganda del Rey, Madrid, Spain

Abstract

This work describes the methodology and limitations found in the design and development of piezoelectric transducers for applications in fluids with COMSOL Multiphysics. In these linear models for the acoustic-structure interaction approximate numerical solutions have been obtained. In order to perform the calculations, simplifications are only valid for low-power sound waves. When different physical systems interact with each other, the solution of one of them cannot be obtained independently without the simultaneous solution of the other, since the forces acting at the interfaces are unknown. These systems are known as coupled systems. Numerical modeling of piezoelectric transducers implies coupling the physics associated with piezoelectric elements, structural elements and fluid elements (with different degrees of freedom), resulting in complex models with difficult convergence. The selection of appropriate mesh refinement, boundary conditions and configuration parameters of the calculation methods is of great importance to obtain the numerical result. The use of high-intensity ultrasound to improve mass transfer efficiency in fluids under supercritical conditions, is presently a novel technique for the extraction of natural products [1]. To scale up the extraction system, a new transducer with a plate radiator has to be designed to get higher power capacity. Additional requirements for the new type of transducer are high quality factor, high efficiency and stable performance under power operation. The analysis of the physical connection between the piezoelectric and structural mechanics of the transducer and the fluid media (linear elastic with attenuation model and equivalent Biot model for porous media) will provide a precise knowledge about the dynamic response of the transducer. The numerical model show the transducer response and distribution of pressure, acoustic intensity and sound pressure levels (SPL) in the fluid medium and on the sample to be treated (porous material) inside the container-extractor. This is important for know the kinetic process of extraction [2]. Figure 1 shows the distribution of pressure inside the extractor and the SPL obtained in a 2D axisymmetric numerical model of the transducer with optimized plate radiator. By modeling the interaction of acoustic field with piezoelectric radiating structure,it has been possible to develop a new transducer design of a circular stepped or grooved plate transducer taking into account the effect of the fluid load. Such ultrasonic device has been designed specifically to optimize it's performance in the process of supercritical fluid extraction, considering the influence of the environment in the dynamic response of the transducer. The transducer geometry studied for this application has increased the amplitude of displacements of the vibrating plate getting more radiation to the environment. The developed models of the transducer allowed the energy radiated in the container to be improved as well as to modify the geometry of the transducer to separate unwanted vibration modes close to the tuned

resonance mode. The vibration modes of the container (where the transducer is placed) have been also explored to check potential interactions with the tuned mode [3].

Reference

1. J.A. Gallego-Juárez, G. Rodríguez, V. Acosta, E. Riera. Power ultrasonics with extensive radiators for industrial processing. Ultrasonics Sonochemistry 17. (2010) 953-964.
2. E. Riera, M. Blaco, A. Tornero, E. Casa, C. Roselló, S. Simal, V. M. Acosta and J.A. Gallego. A pilot scale Ultrasonic System to Enhance Extraction Processes with dense gases. INTERNATIONAL CONGRESS ON ULTRASONICS: Gdańsk 2011. AIP Conference Proceedings, Volume 1433, pp. 358-362 (2012)
3. I. Tudela, V. Saez, M. Deseada Esclapez, P. Bonete, H. Harzali, F. Baillon, J. Gonzalez-Garcia, O. Louisnard. Study of the influence of transducer-electrode and electrode-wall gaps on the acoustic field inside a sonoelectrochemical reactor by FEM simulations. Chemical Engineering Journal 171. (2011). 81-91.
4. F.J. Trujillo, Kai Knoerzer. Modeling the acoustic field and streaming induced by an ultrasonic horn reactor. Chapter 11 in Innovative Food Processing Technologies: Advances in multiphysics simulation. Edited by Kai Knoerzer, Pablo Juliano, Peter Roupas and Cornelis Versteeg. IFT Press and WILEY-BLACKWELL. (2011) 233-264.

Figures used in the abstract

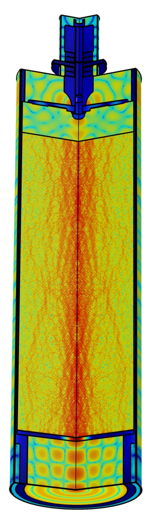

Figure 1