Near-Wall Dynamics of Microbubbles in an Acoustical Trap

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Abstract

Understanding the interactions between microbubbles and surfaces is key to the successful deployment of microbubbles in a range of applications. Two important examples are their use as a drug delivery mechanism, and their potential use of acoustically driven bubbles as microscale sensors. Drug delivery with bubbles involves sonication at high frequency close to a boundary, and sensing with bubbles typically involves deploying the bubbles in microchannels.

In a joint project with Oxford and UCL, researchers at the National Physical Laboratory are developing a new instrument for microbubble characterisation: NPL sono-optical tweezers. In a typical experiment with this set-up a microbubble is trapped close to a wall by an acoustic field at a low frequency (163 kHz), and is excited by an independent acoustic field at a higher frequency (2 MHz). The response of the bubble to these fields is a complicated problem, but the understanding of the response is necessary for efficient analysis of the measurements.

This work presents an axisymmetric finite element model of a bubble undergoing sonication near to a wall. The model couples two COMSOL Multiphysics® modules to exploit the strengths of each module in the region where the capabilities of that module are key.

The presence of a wall introduces an asymmetry that may invalidate the assumption of sphericity used by most semi-analytical models of microbubbles. Testing this hypothesis requires usage of the CFD Module in the region directly surrounding the bubble, so that two-phase compressible flow can be used to simulate the bubble deformation accurately.

The use of two distinct acoustic frequencies in the experimental work means that the problem cannot be solved in the frequency domain and a transient model is necessary, and the excitation of the bubble means that the scattered signal must be able to escape the model domain. The acoustic module is used in the region further away from the bubble to enable radiation conditions and point sources to be used to define appropriate boundary and driving conditions.

This paper will report the development and validation of the model, including work comparing the results of the finite element model to a recently-developed one-dimensional model for

bubble behaviour close to a wall that makes the assumption of sphericity.