INVESTIGATING BUBBLE DYNAMICS IN A BLOOD-FILLED CAVITY ENCLOSED IN A BLOOD VESSEL

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Introduction

Ultrasound and microbubble technology has been used for various therapeutic applications, including the breakup of urinary stones, diagnostic imaging, and gene delivery. Recent advancement in ultrasound is using microbubble oscillation to enhance the effect of the drug in chemotherapy [1]. Since the compressibility of a bubble is large, the bubble oscillates with ultrasound. The oscillation of the intravascular microbubbles increases the permeability of endothelium, thus increasing the drug uptake to the tumor site. The dynamic of a bubble in a liquid confined within an elastic solid is investigated in this study to understand the microbubble behavior in a blood vessel. An external acoustic field is applied to the elastic confinement to obtain volume oscillations.

Methods

The physical system, shown in Figure 1, comprises a bubble in blood, modeled as a compressible non-Newtonian liquid confined in a blood vessel, an elastic solid. The motion of solid and liquid are described by the Navier and Equation of motion. For the constitutive model of non-Newtonian liquid, the power-law model is chosen. To increase the stability of the bubble, the bubble is encapsulated with an incompressible, Kelvin-Voigt shell [2-3]. It is assumed that the pressure inside the confinement has a linear relation with the volume change of the confinement. Finally, coupled differential equations are obtained and solved with explicit Runge-Kutta formulation in MATLAB.

Results

The effects of ultrasound frequency, shell rigidity ($\boldsymbol{G_s}$), and the ratio of the initial shell radius to the bubble radius are investigated on the oscillation period and maximum value of bubble radius. The physical parameters are given in Table 1.

Shell viscosity	1 P
Liquid viscosity	0.01 P
Shell density	1100 kg/m^3
Elastic modulus	2.2 GPa
Vapor pressure in bubble	2300 kPa

Table 1: Physical Properties.

Discussion

As observed from Figure 2, at higher rigidity of shell and frequency of external field, maximum bubble radius decreases which will cause bubble burst. Furthermore, the oscillation period of the bubble can be adjusted by the frequency of the external field.

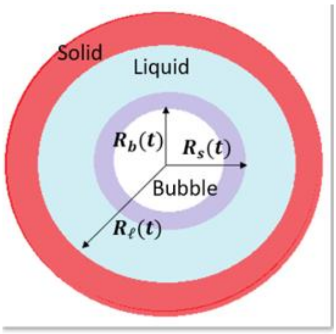

Figure 1. Bubble encapsulated with shell in a blood vessel.

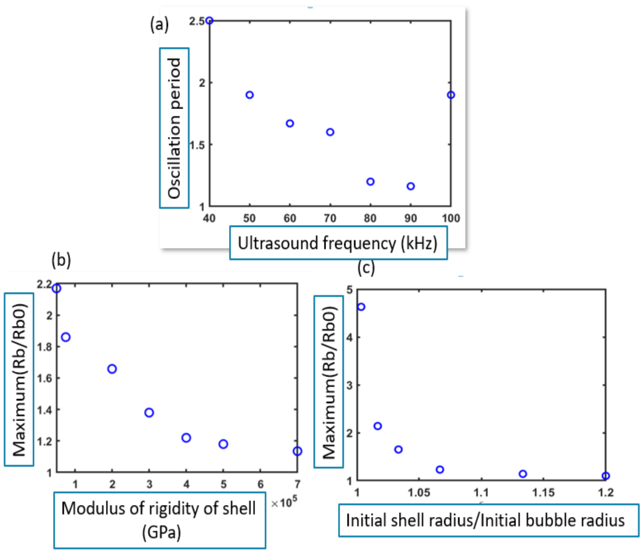

Figure 2. Effects of (a) ultrasound frequency on oscillation period of the bubble; (b) rigidity of shell and (c) initial shell radius value on the maximum value of bubble radius.

References

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