THEORETICAL STUDY OF MICROBUBBLE DYNAMICS UNDER THE ACTION OF ULTRASOUND FIELDS

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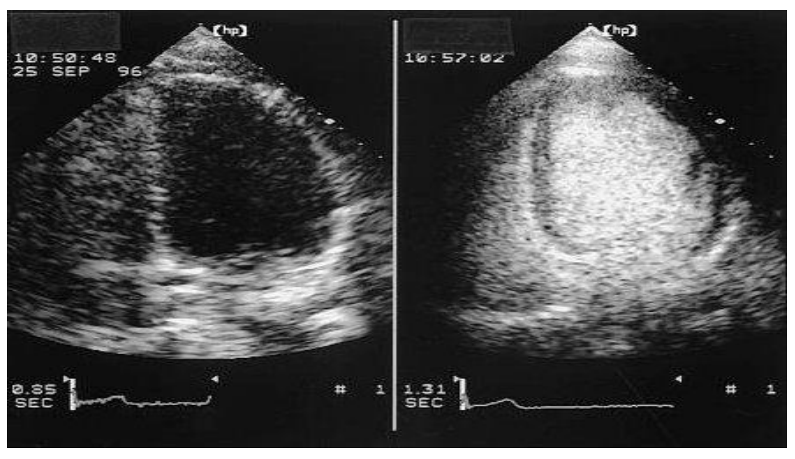
INTRODUCTION

Ultrasound contrast agents (UCAs) used to improve medical image. There are a lot of Contrast agents substance in the market which has different Parameters with different use for medical purposes. For that, there are a lot of models which describe the motion of bubble under the action of Ultrasound.

UCAs models are derived for the radius of the bubble as a function of time in response to a time dependent driving pressure. The most fundamental of the nonlinear models is a second order, ordinary differential equation, called the Rayleigh-Plesset (RP) equation.



MODELS

Microbubble Models
- Free Gas bubble
- Encapsulated bubble

Model for free gas bubble: **Rayleigh-Plesset** Equation

$$\rho\left(\ddot{R}R+\frac{3}{2}\dot{R}^2\right)=p_0\left(\frac{R_0}{R}\right)^{3\gamma}-p_0-P(t)$$

Model for Encapsulating bubble:

- **Hoff's** Model

$$\rho_l\left(R\ddot{R}+\frac{3}{2}\dot{R}^2\right)=Po\left(\left(\frac{R_0}{R}\right)^{3k}-1\right)-P(t)-4\mu_l\frac{\ddot{R}}{R}-12\mu_s\frac{d_{s,0}R_0^2}{R^3}\frac{\dot{R}}{R}-12G_s\frac{d_{s,0}R_0^2}{R^3}\left(1-\frac{R_0}{R}\right)$$

- **Marmottant's** model

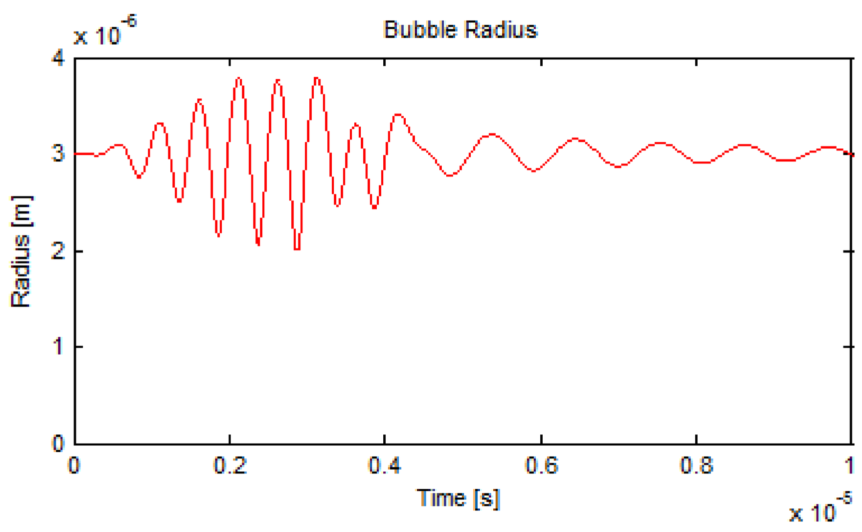
$$\rho_l\left(R\ddot{R}+\frac{3}{2}\dot{R}^2\right)=\left(p_0+\frac{2\sigma(R_0)}{R_0}\right)\left(\frac{R_0}{R}\right)^{3k}\left(1-\frac{3k}{c}\dot{R}\right)-p_0-\frac{2\sigma(R_0)}{R}-4\mu_l\frac{\dot{R}}{R}-\frac{4k_s\dot{R}}{R^2}-p(t)$$

Where **R** is the bubble Radius ,P is the pressure .

FREE GAS BUBBLE

Rayleigh-Plesset Equation

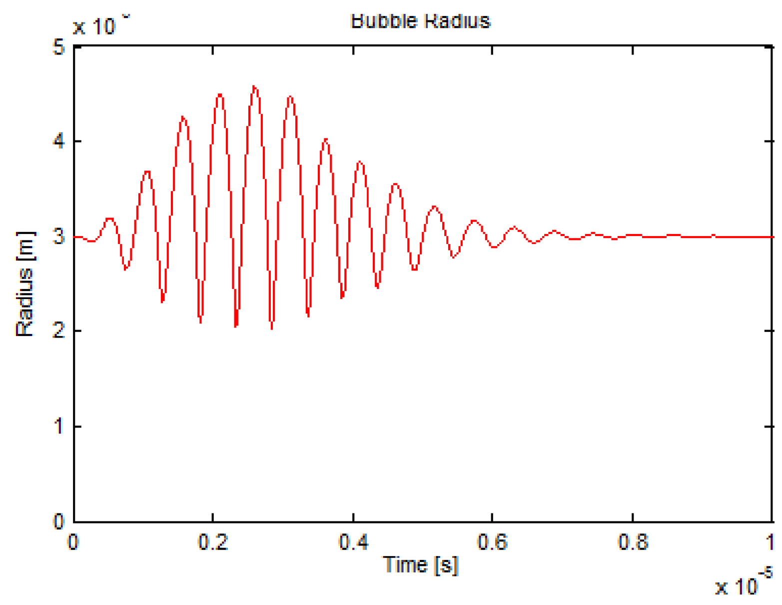
With center frequency 2 MHz and using water as liquid, Bubble response will be:

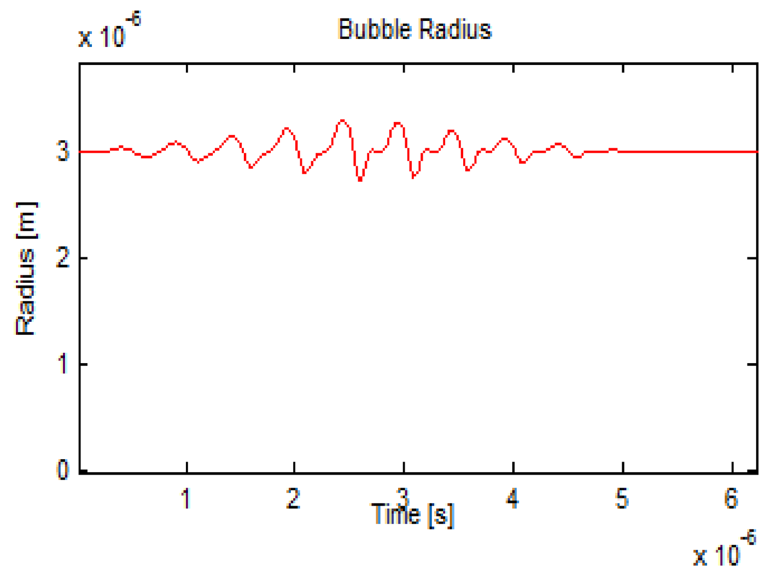


ENCAPSULATING BUBBLE

Hoff's Model

For **Sonazoid**©:
- Radius R0=3µm;
- pulse amplitude=0.3Mpa
- Pulse length 5 cycles
- frequency 2 MHz

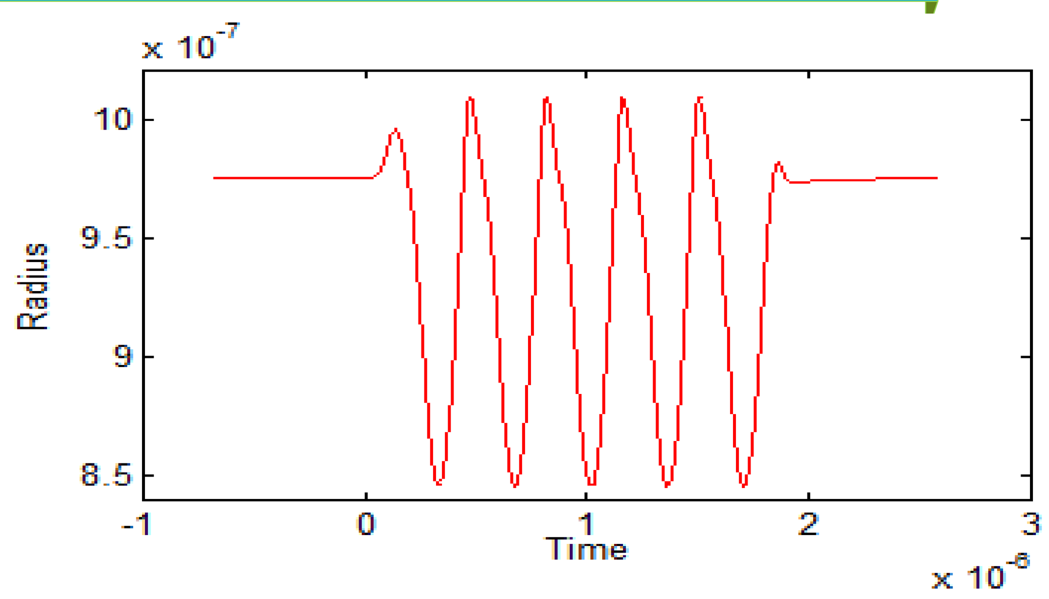




For **Albunex**©
- Radius R0=15µm;
- pulse amplitude=0.3Mpa
- Pulse length 5 cycles
- frequency 2 MHz

Parameters and Values(Tab 2.3)		
Parameter	Value	Description
p_0	1.013 x 105 Pa	Ambient pressure
ρ	1000 kg/m3	Density of liquid
γ	1.4	Polytropic exponent
Shell parameters Albunex©		
δ	15 nm	Shell thickness
G_s	88,8 MPa	Shell elastic modulus
μ_s	0,5 Pa s	Shell viscosity
Sonazoid©		
δ	4 nm	Shell thickness
G_s	50 MPa	Shell elastic modulus
μ_s	0.8 Pa s	Shell viscosity

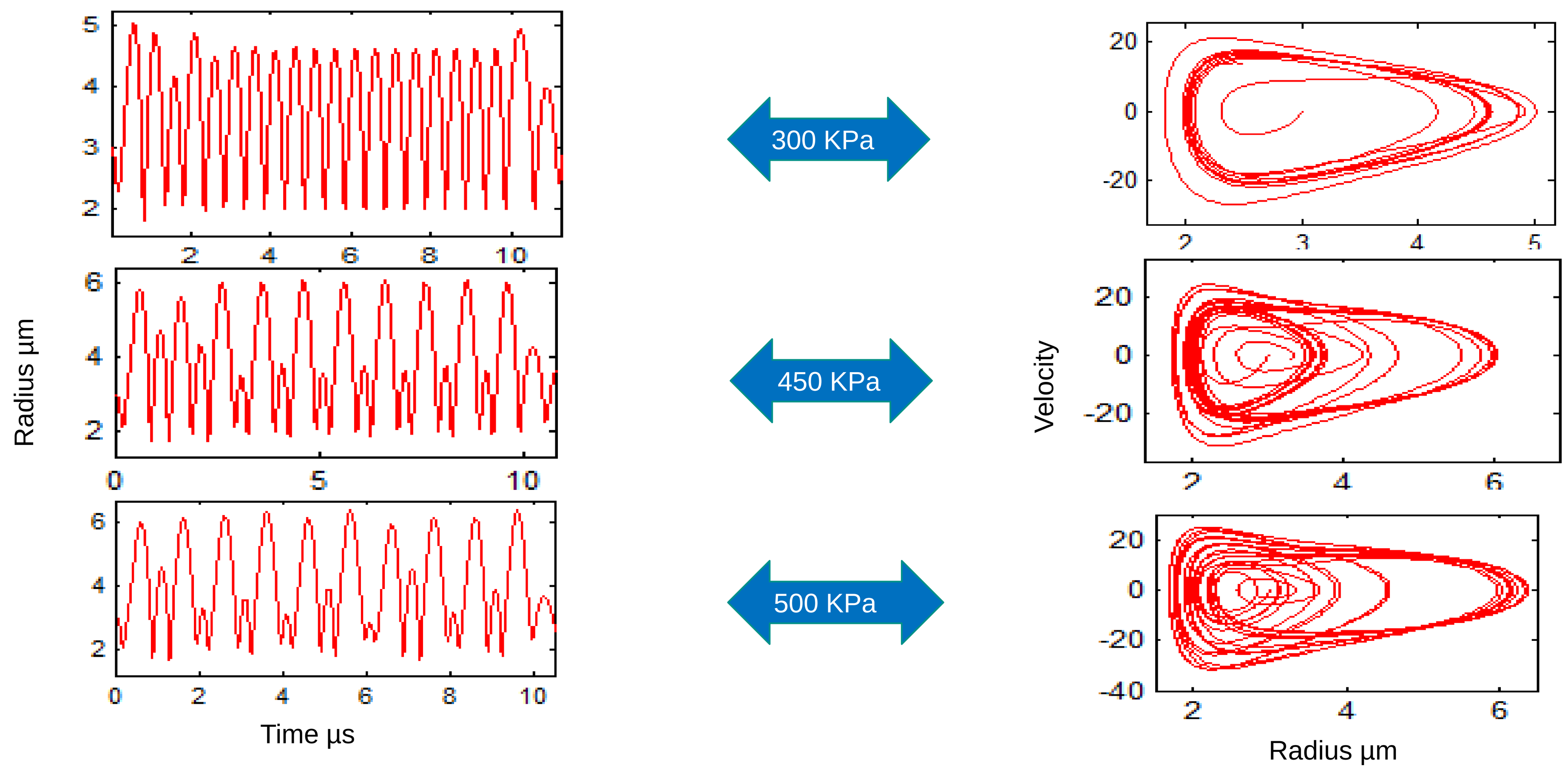
Marmottant's Model



- Radius Buckling R_0=0.975 µm
- χ=1 N/m; ks=15x10^{-9} N
- $\sigma_{break\ up}$>1 N/m
- frequency 2.9 MHz

NONLINEAR BEHAVIOR

- The bubble behaves as a nonlinear oscillator at high amplitude
- With increasing the pulse amplitude with increasing Chaotic motion



CONCLUSIONS

- Hoff model depends on viscoelastic parameters of the shell material.
- Marmottant depend on surface tension (buckling radius, a shell compressibility, and a break-up shell).
- The fundamental assumptions of the models, such as spherically symmetric and stationary bubbles are unrealistic for contrast agents in the body.