COMSOL CONFERENCE
BANGALORE 2011
NOVEMBER 4-5

Modeling of Wave Propagation in Particulate Composites

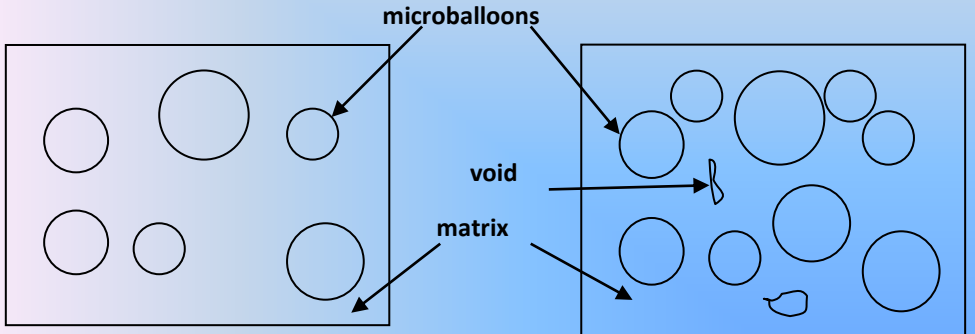
Phani Mylavarapu, Srivathsa Boddapati

Defence Metallurgical Research Laboratory, Kanchanbagh

Outline

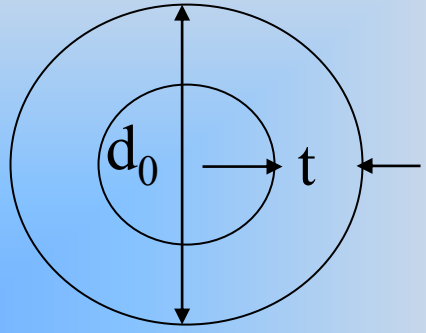
- Introduction
- Problem Definition
- FEM Modeling
- Approach
- Results and Discussions
- Conclusions and Future work

Syntactic foams (SF)

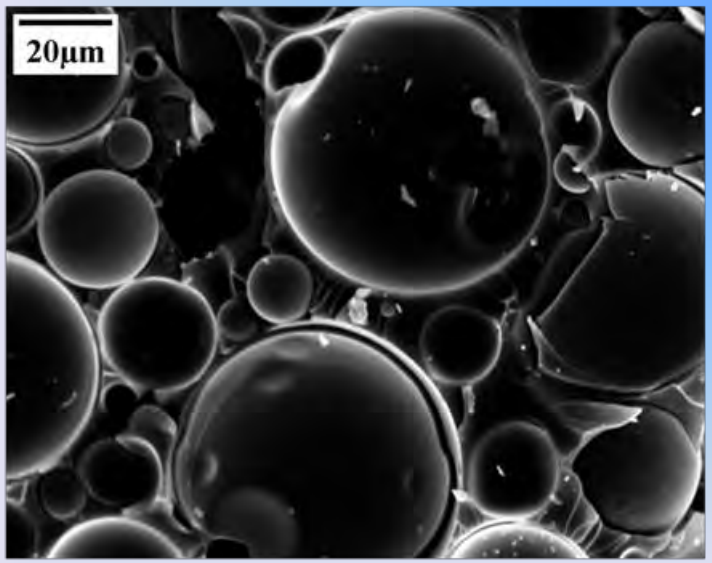


Two phase

Three phase



$\eta_i = r_i/r_o$



SEM Image of Syntactic Foams

Underwater explorer

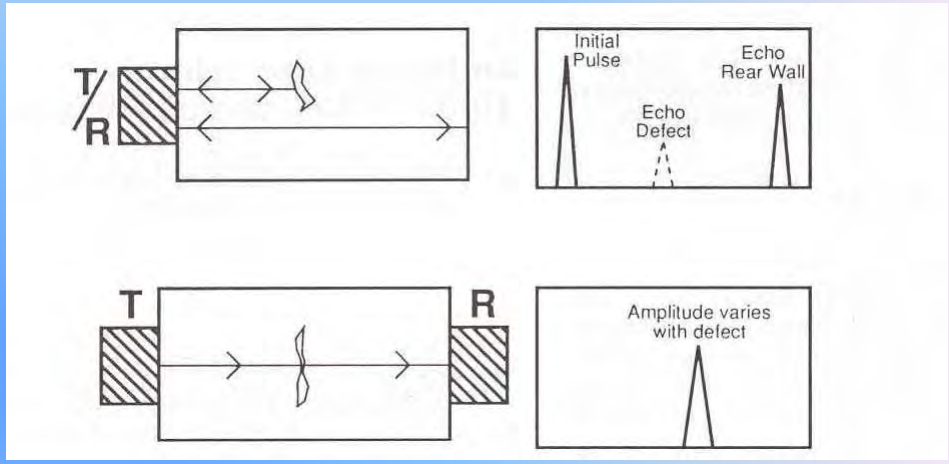
Courtesy: Oceanexplorer

Ultrasonic Testing

- Attenuation

$$\frac{A}{A_0} = e^{-\alpha x}$$

$$\alpha = \alpha_s + \alpha_a + \alpha_r$$



E. Segal and J. L. Rose, in: Research Techniques in Non-Destructive Testing, Vol. IV,R. S. Sharpe (Ed.), pp. 275–316. Academic Press, London (1980).

- Ultrasonic Velocity
  - Longitudinal Velocity (V_l) $L = \rho * V_l^2$
  - Shear Velocity (V_s) $G = \rho * V_s^2$

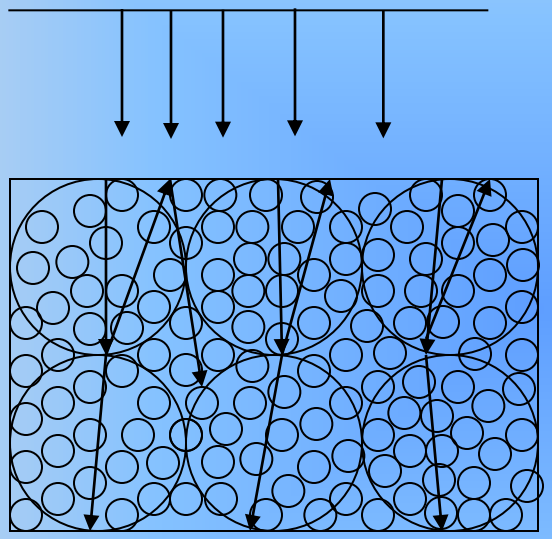
$$E = \frac{G(3L - 4G)}{L - G}$$

$$\nu = \frac{L - 2G}{2(L - G)}$$

Modulus Predicted from UT

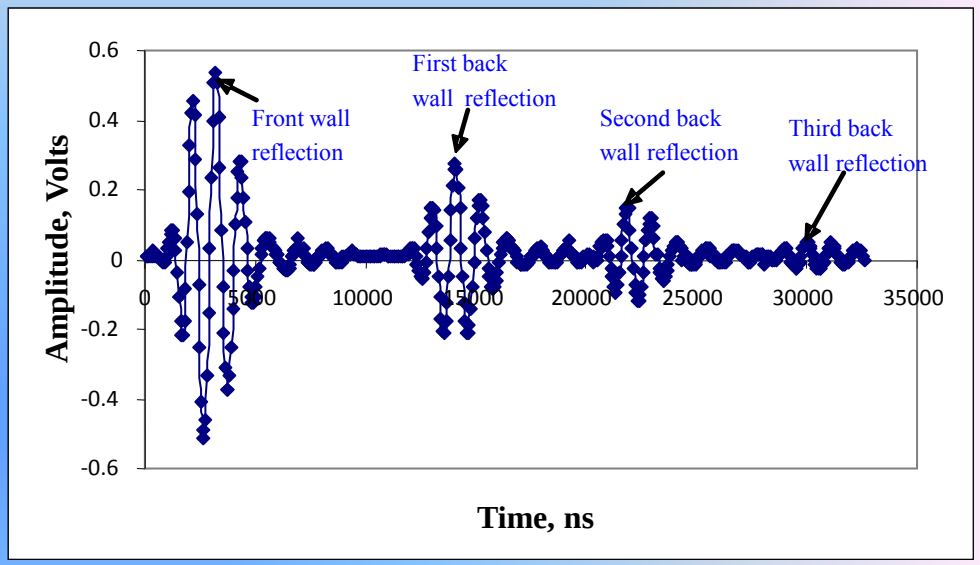
Sample Name	Predicted UI Modulus, MPa	SHPB Modulus, MPa	Quasi -Static Modulus, Mpa
Pure Epoxy	4476±183	4272-5084	2320±40
S2210	3667±89	3310-3903	2156
S2250	2173±41	1701-2244	1512
S3210	4071±45	3048-4099	2310
S3250	2800±88	2146-2808	2052
S3840	3481±25	3244-3664	2351
K4650	3385±109	2901-3446	2473

Cluster Interaction With Ultrasonic Energy



Problems with Ultrasonic Testing

- Difficult to distinguish the reflections originating from epoxy or particle or epoxy/particle interface
- Waves due to multiple reflections



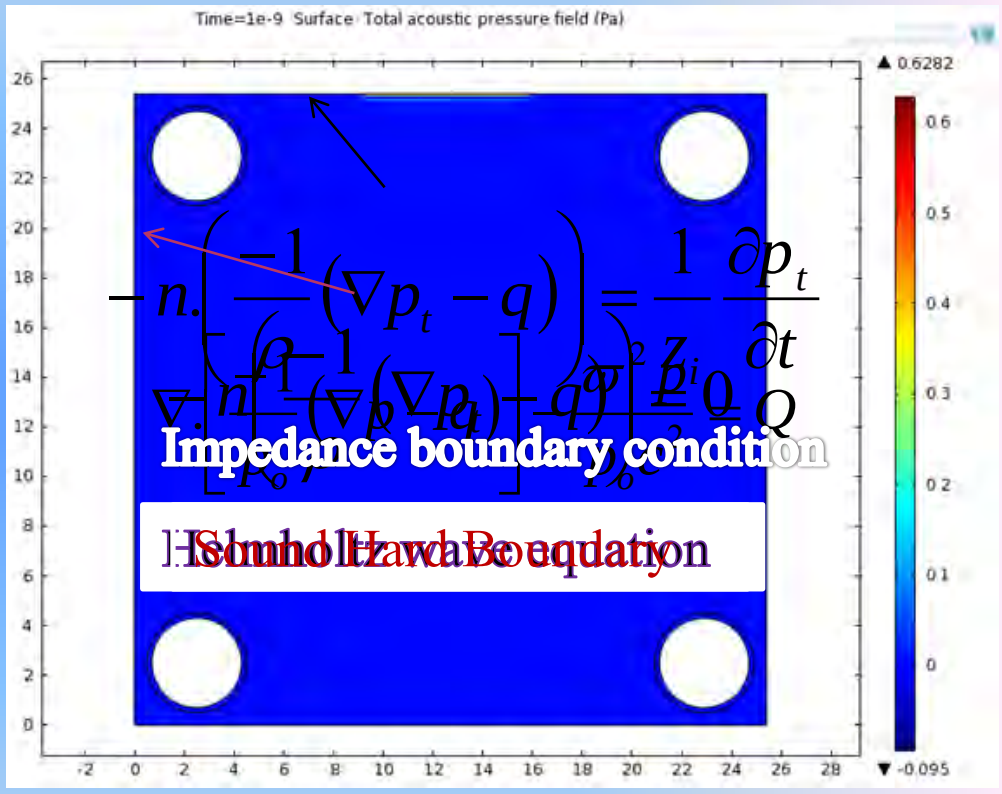
S2230

$$\frac{\lambda}{a} \succ 1$$ Typically UT performed

$$\frac{\lambda}{a} = 1 \quad \& \quad \frac{\lambda}{a} \prec 1$$ Experimentally difficult

Modeling using COMSOL

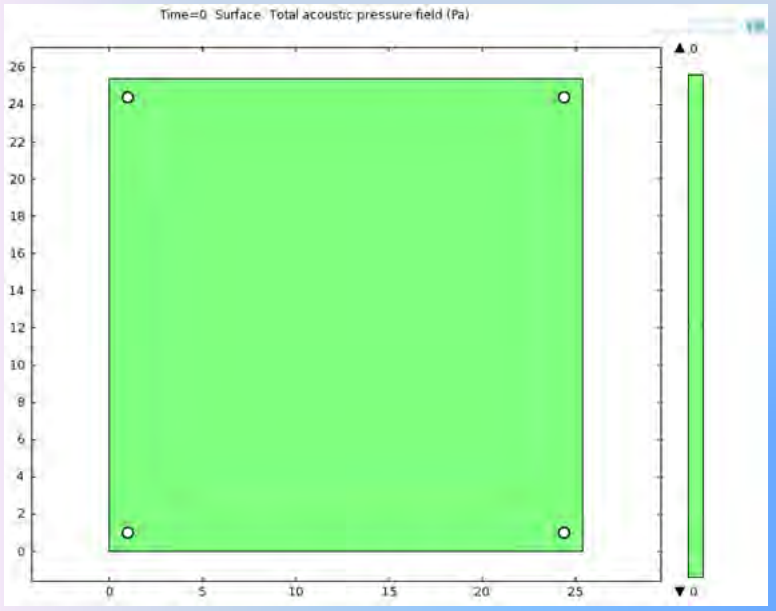
- BC's available for source of excitation:
  - Gaussian point source
  - Pressure
  - Plane wave radiation
- BC's available for reflection/transmission between interfaces
  - Impedance

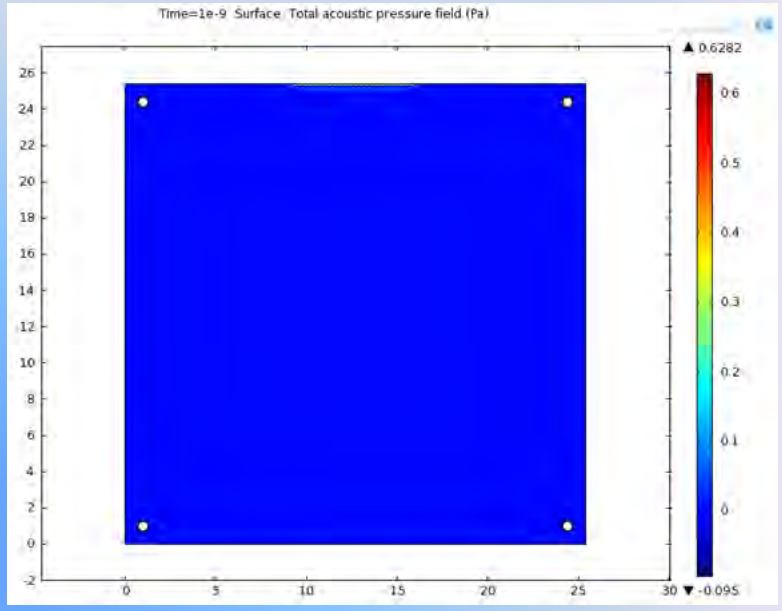


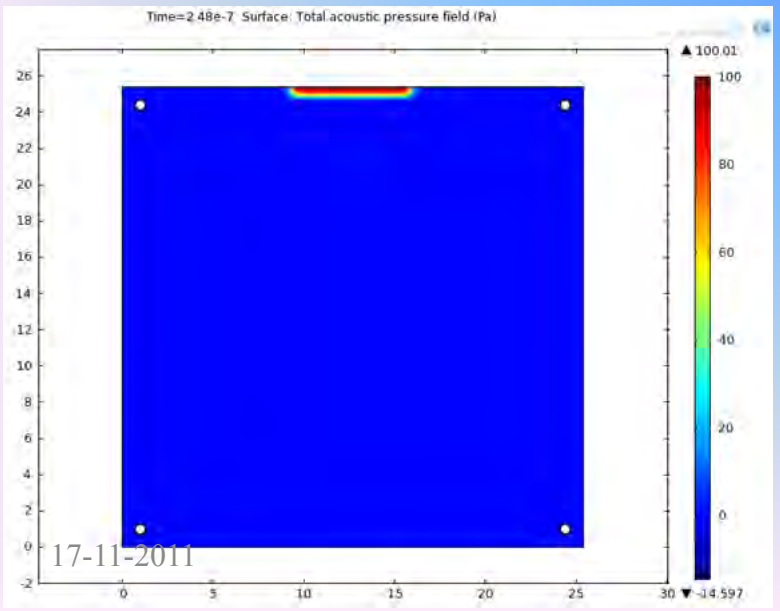
Mesh Details and CFL

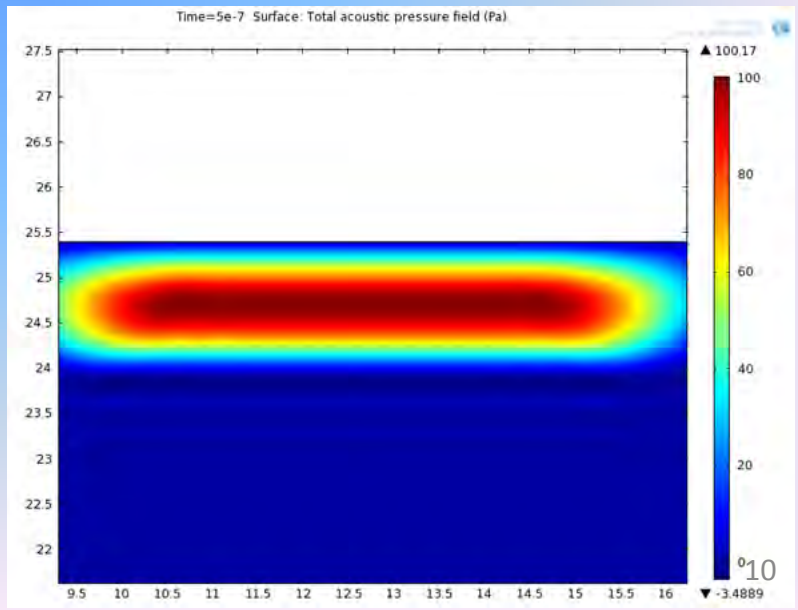
- 0.285 element size
- ƛ/10
- Same element size for all models
- CFL Criteria: 5e-9 s

Case 1: $\frac{\lambda}{a} \succ 1$

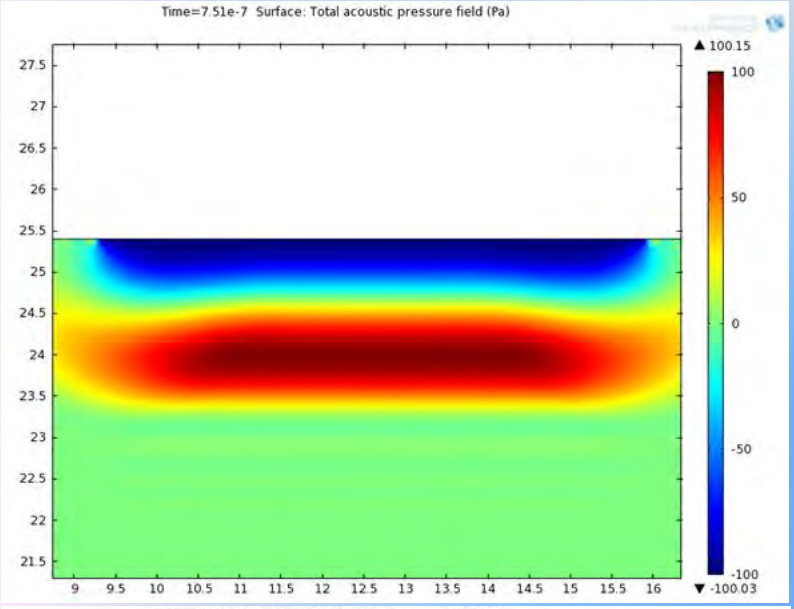


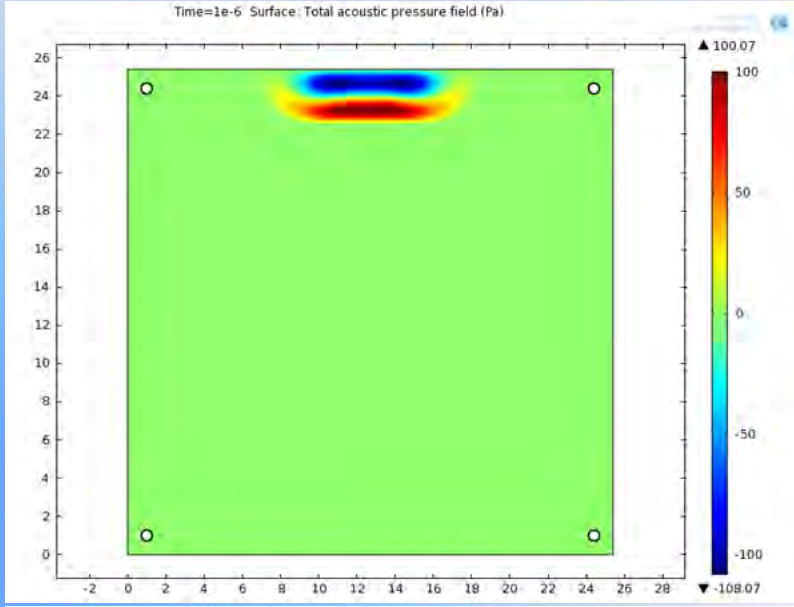


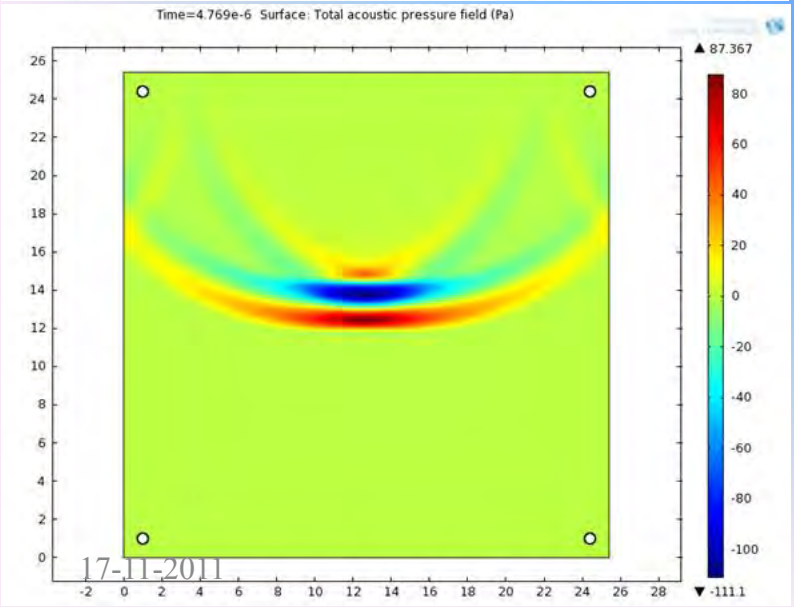


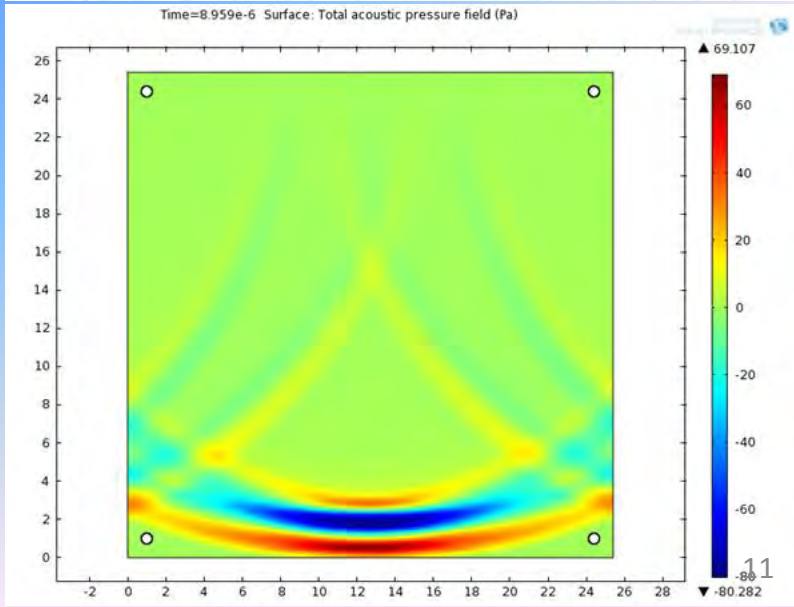


Case 1 (contd…)

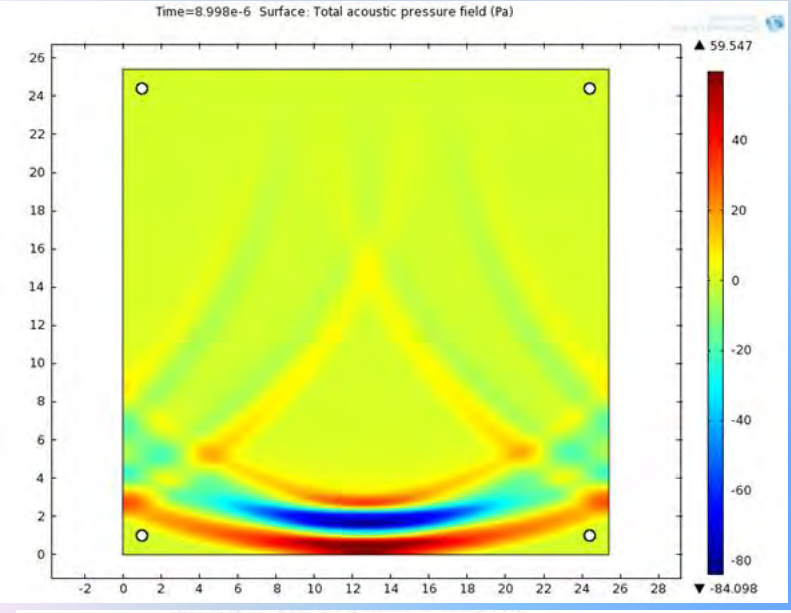

Time=7.51e-7 Surface: Total acoustic pressure field (Pa)
▲ 100.15
▼ -100.03

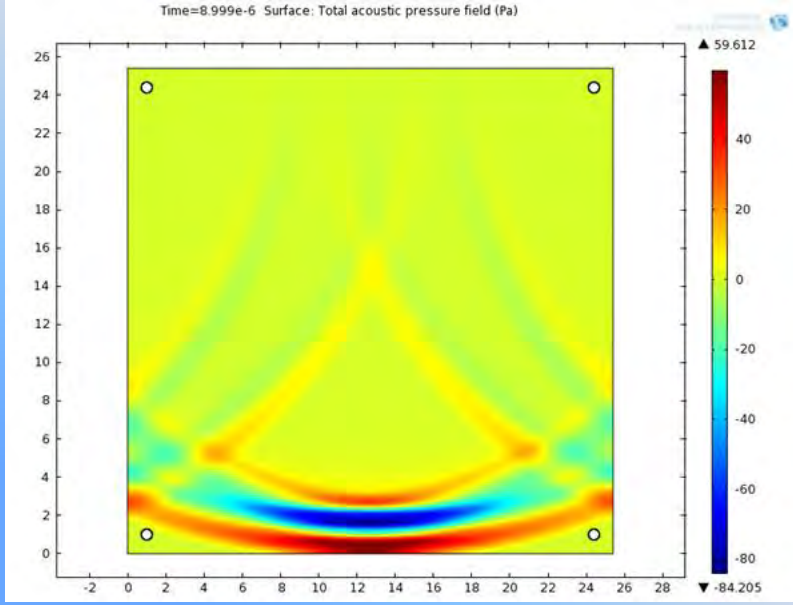

Time=1e-6 Surface: Total acoustic pressure field (Pa)
▲ 100.07
▼ -108.07

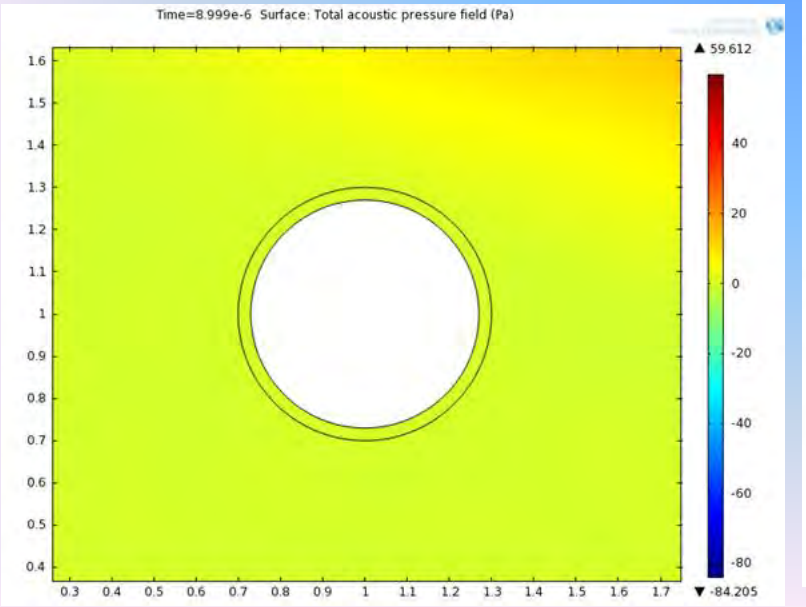

Time=4.769e-6 Surface: Total acoustic pressure field (Pa)
▲ 87.367
▼ -111.1

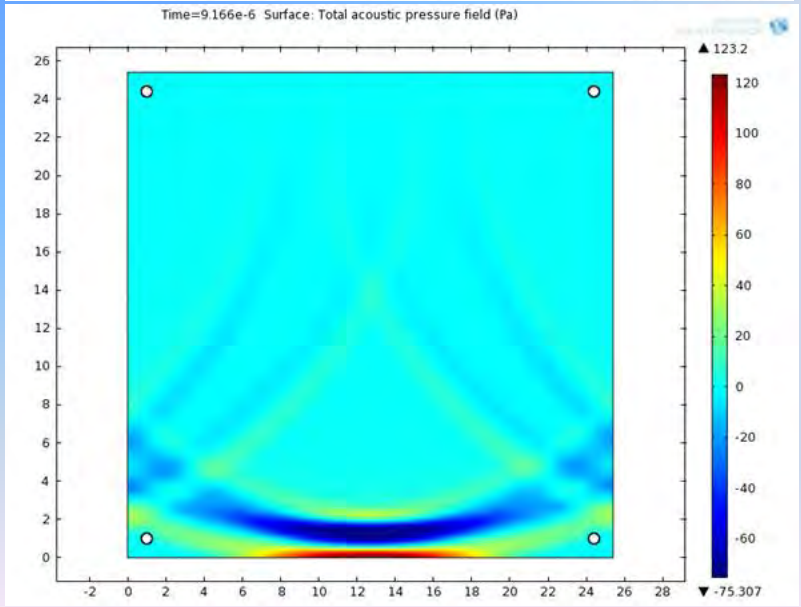

Time=8.959e-6 Surface: Total acoustic pressure field (Pa)
▲ 69.107
▼ -80.282

Case 1 (contd…)

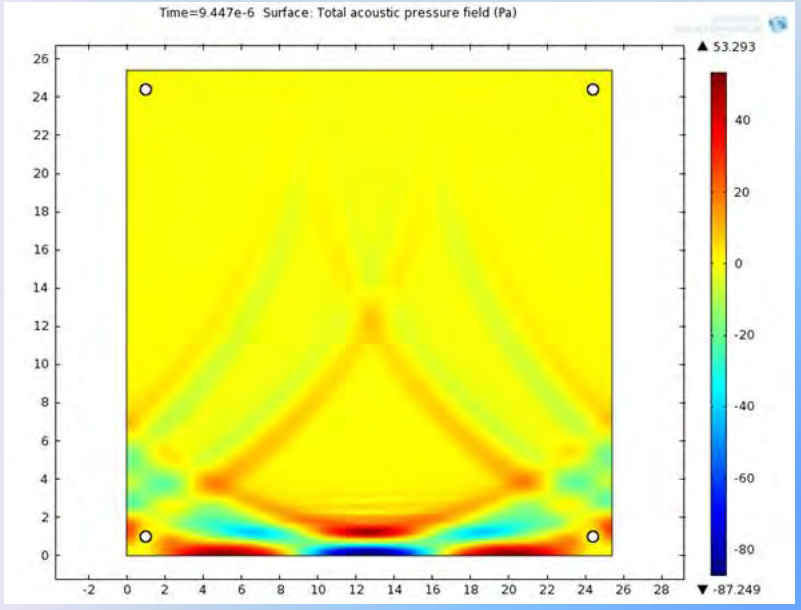

Time=8.998e-6 Surface: Total acoustic pressure field (Pa)
▲ 59.547
▼ -84.098

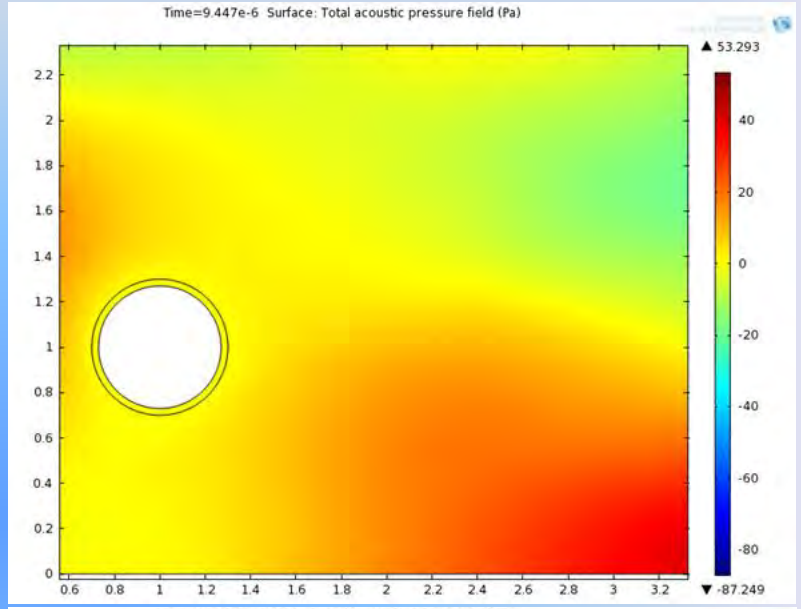

Time=8.999e-6 Surface: Total acoustic pressure field (Pa)
▲ 59.612
▼ -84.205

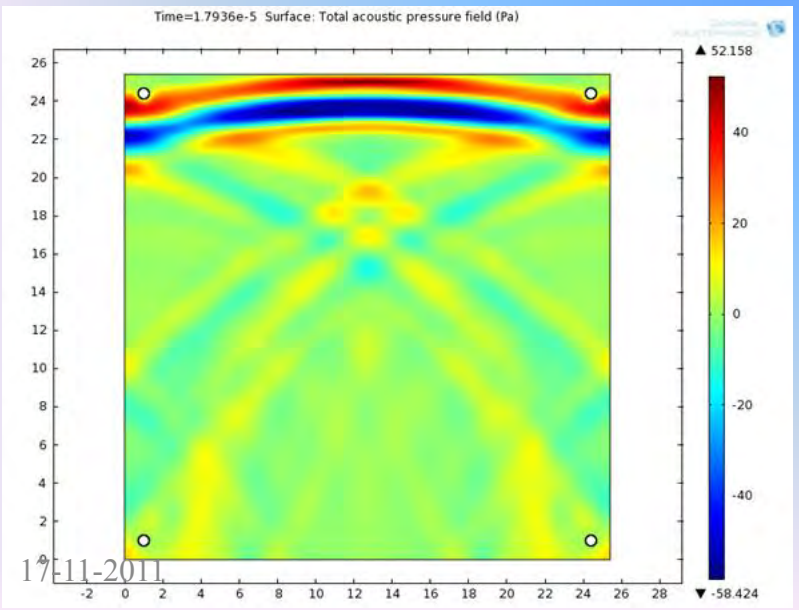

Time=8.999e-6 Surface: Total acoustic pressure field (Pa)
▲ 59.612
▼ -84.205

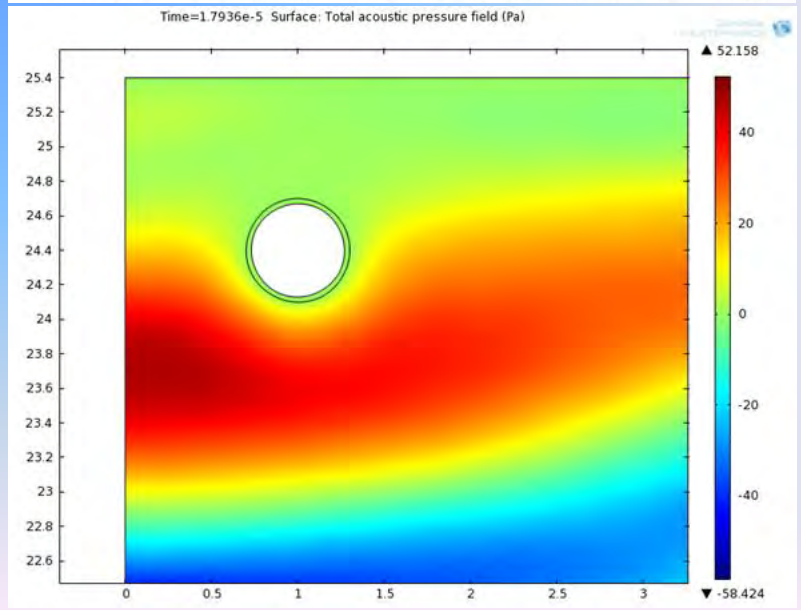

Time=9.166e-6 Surface: Total acoustic pressure field (Pa)
▲ 123.2
▼ -75.307

Case 1 (contd…)

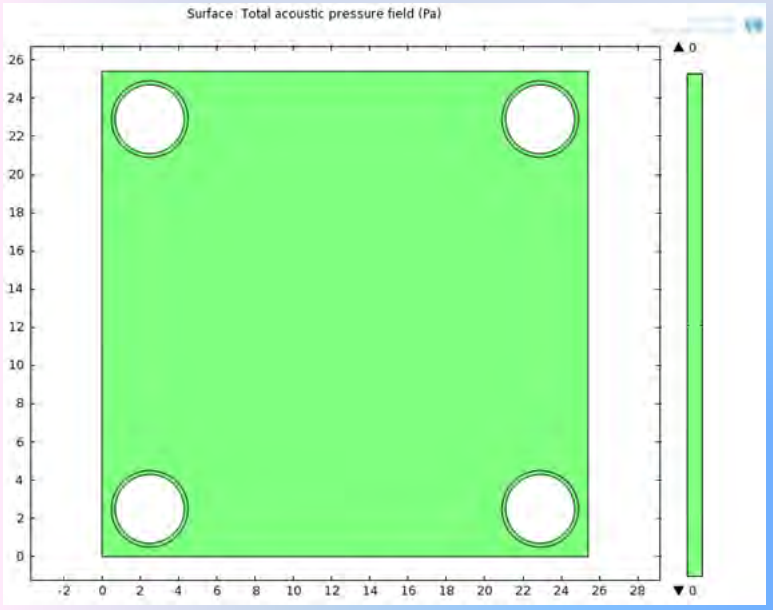

Time=9.447e-6 Surface: Total acoustic pressure field (Pa)
▲ 53.293
▼ -87.249

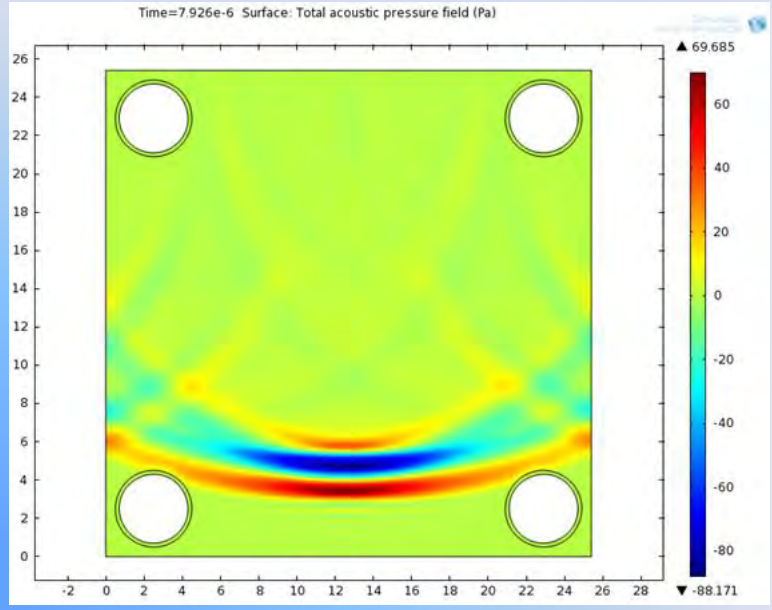

Time=9.447e-6 Surface: Total acoustic pressure field (Pa)
▲ 53.293
▼ -87.249

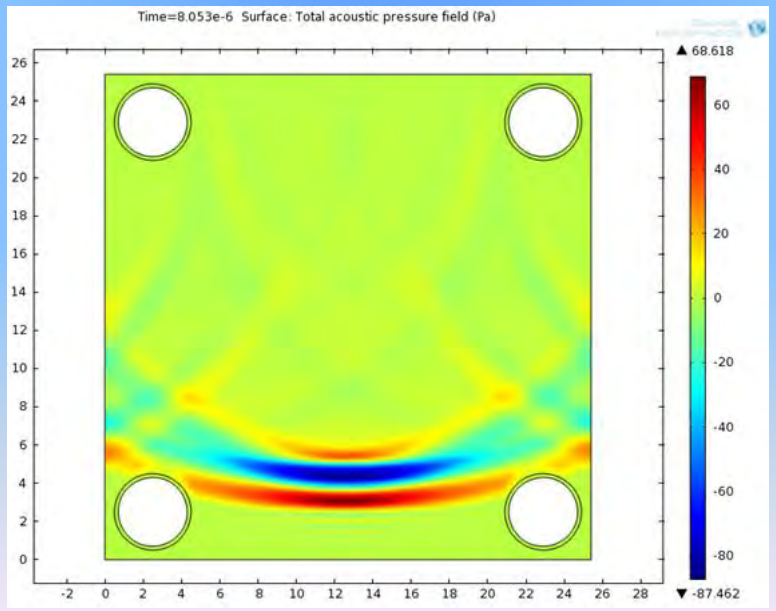

Time=1.7936e-5 Surface: Total acoustic pressure field (Pa)
▲ 52.158
▼ -58.424


Time=1.7936e-5 Surface: Total acoustic pressure field (Pa)
▲ 52.158
▼ -58.424

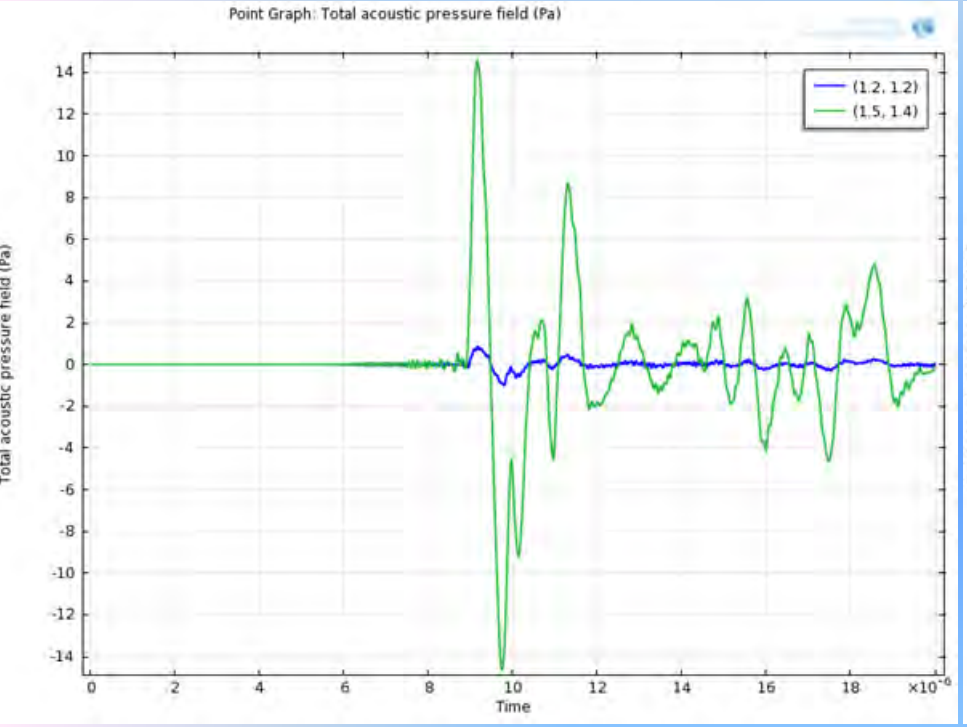
$$\frac{\lambda}{a} \prec 1$$

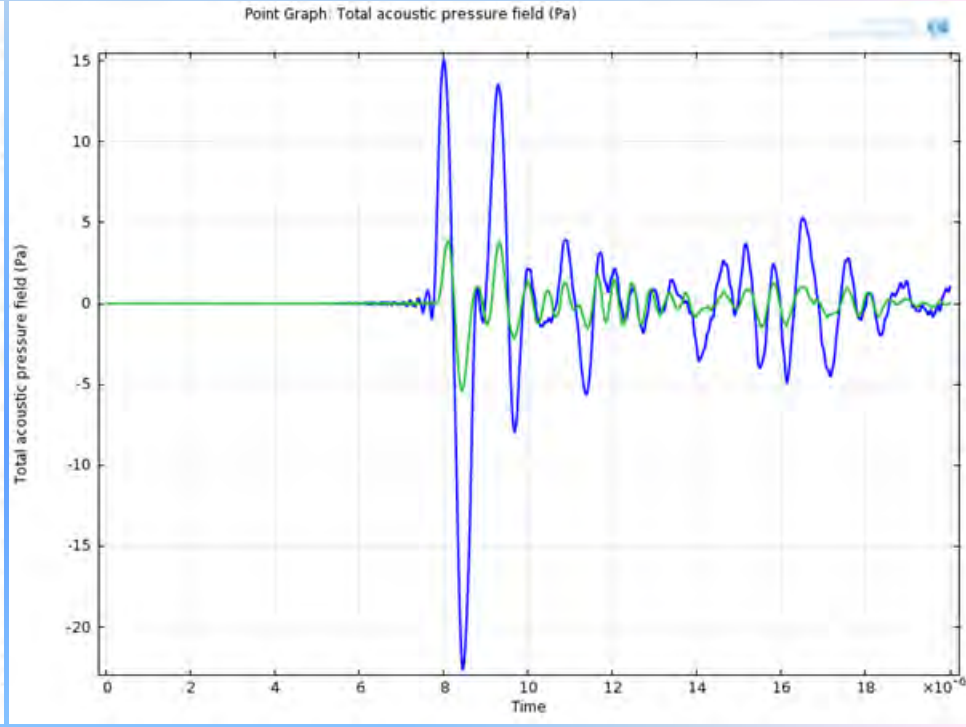






Comparison of pressure in the particle

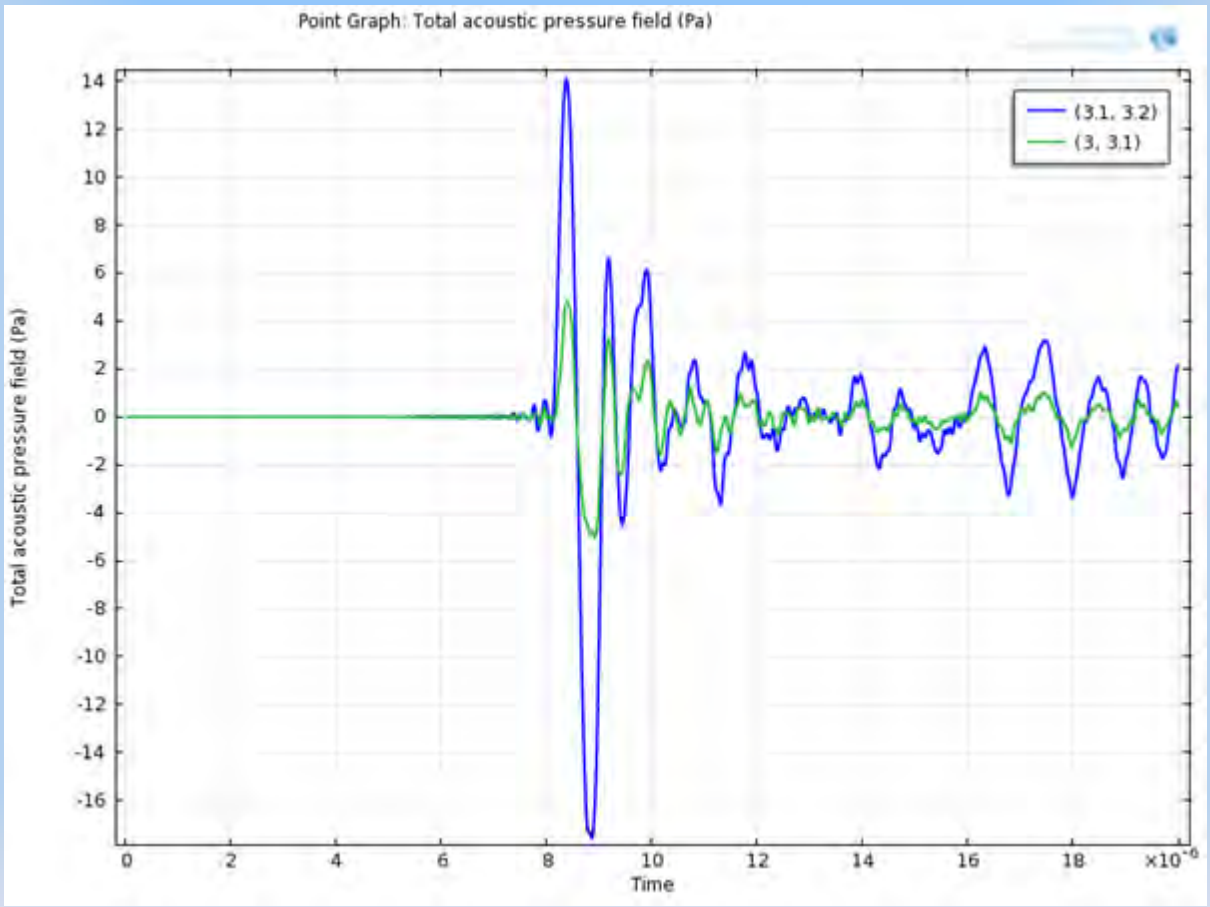




$$\frac{\lambda}{a} \succ 1$$

$$\frac{\lambda}{a} \prec 1$$

$$\frac{\lambda}{a} = 1$$



Conclusions and Future Work

- Effect of ratio of wavelength to particle size on reflection studied.
- Ratios of less than, greater than and equal to 1.
- Multiple reflections from particles

Acknowledgements

- Director, DMRL
- Dr. Nikhil Gupta, Brooklyn University