Numerical analysis of an ultrasonic technology for food dehydration process intensification

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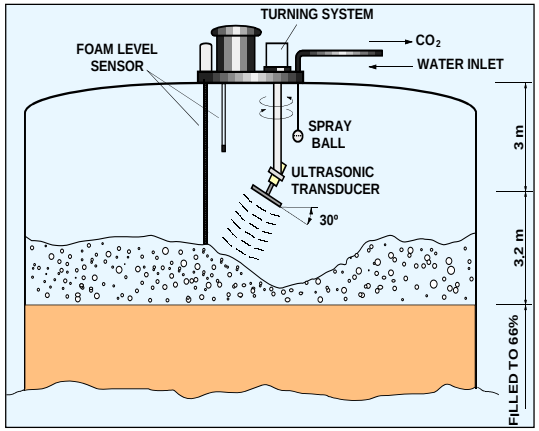
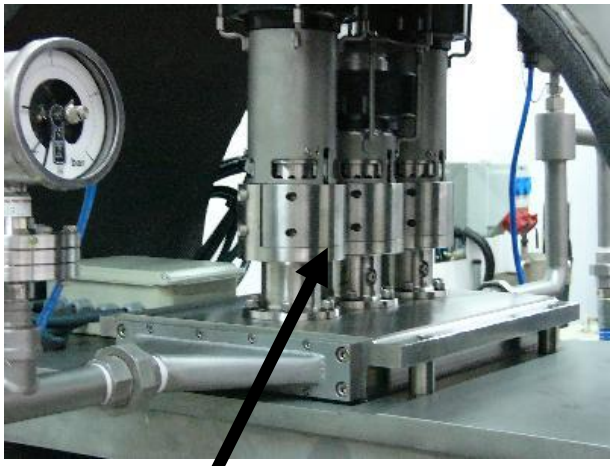
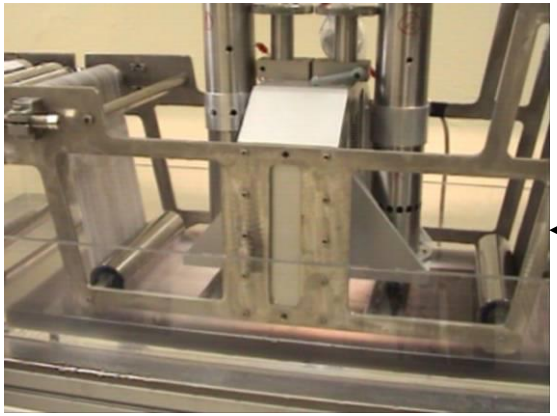
BACKGROUND

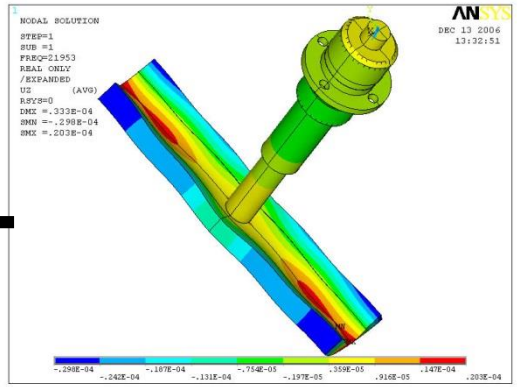
Ultrasonic defoaming

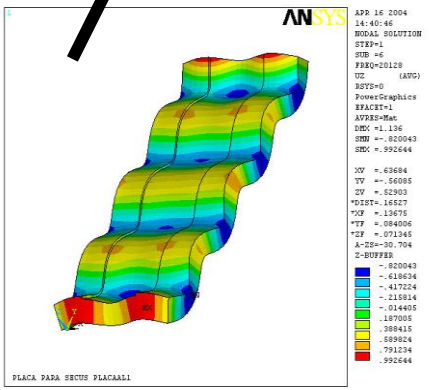


Enhancement of the dispersion of solid particles in liquids





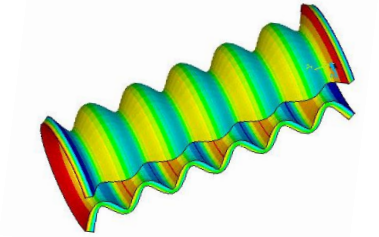


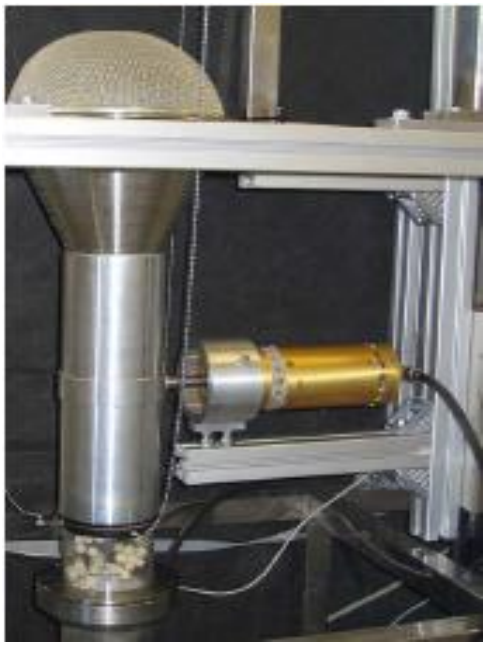


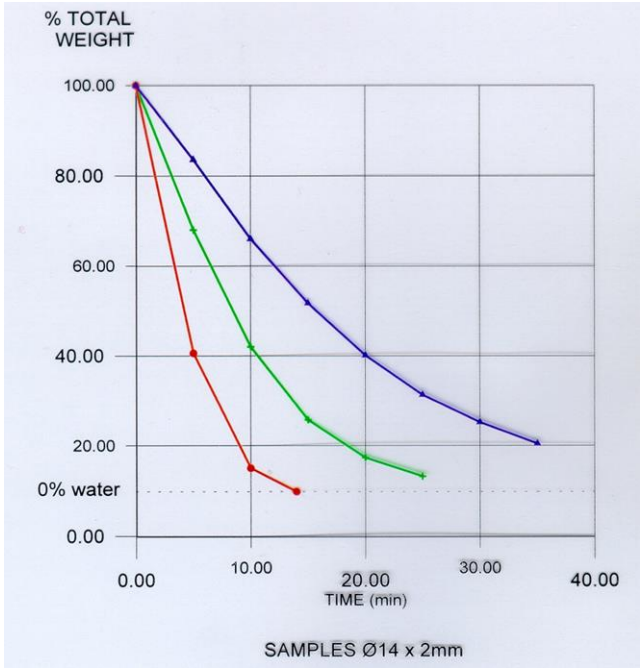
US system for textile washing

BACKGROUND

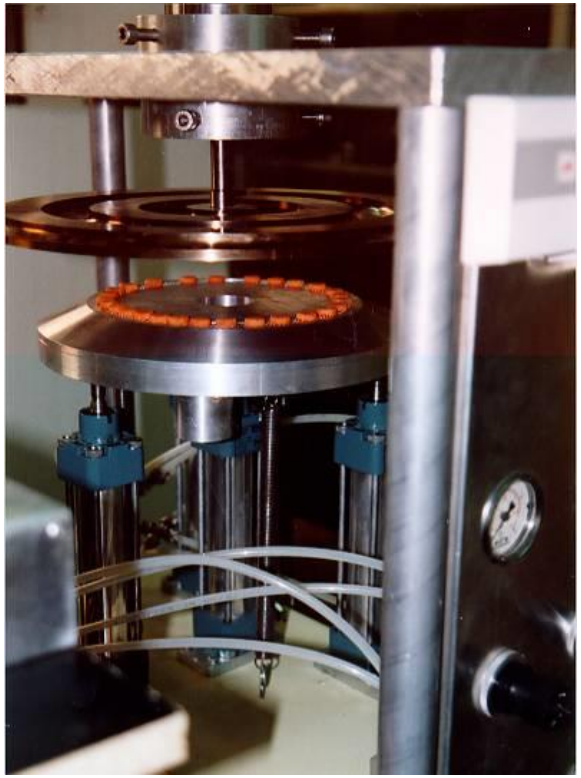
Mass transfer enhancement in food drying



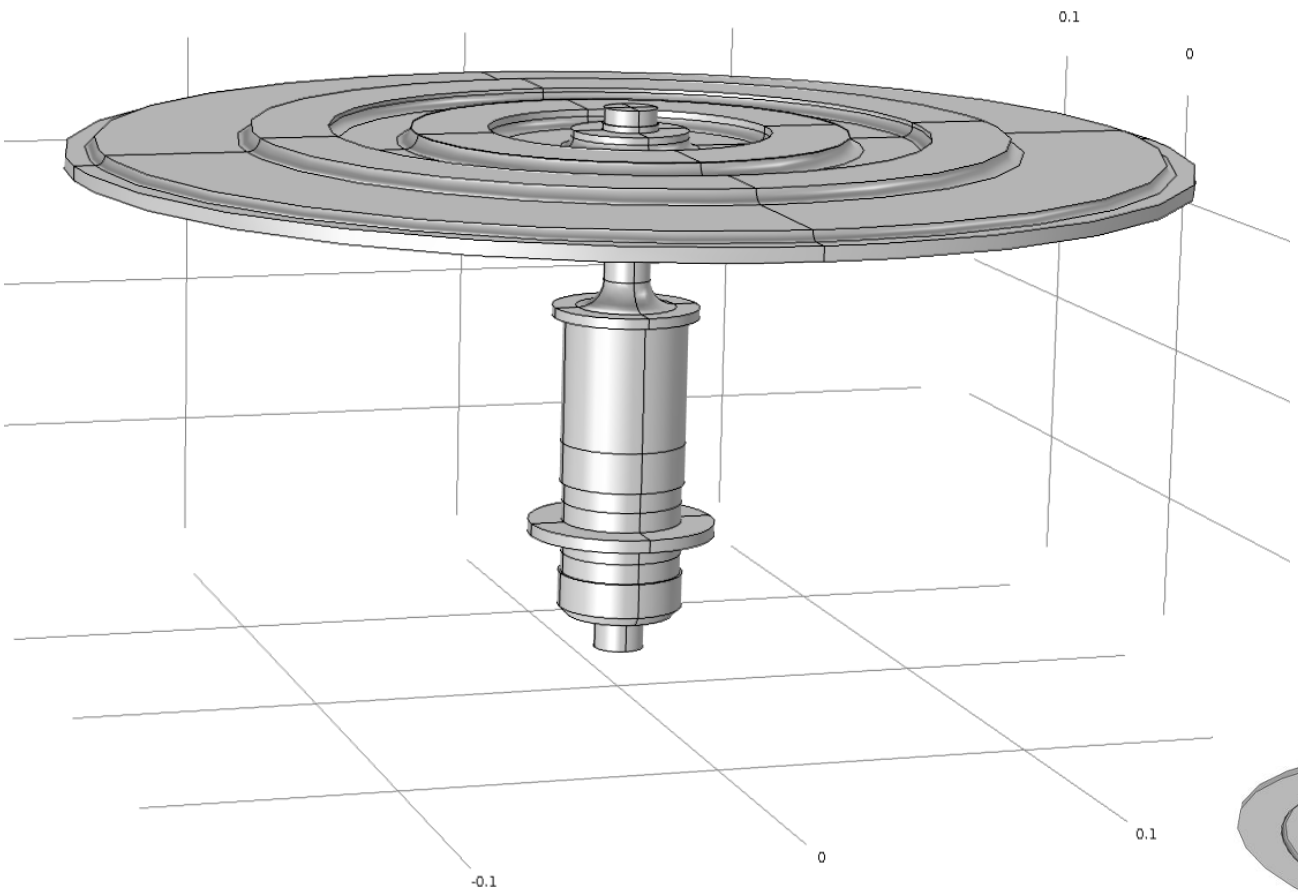


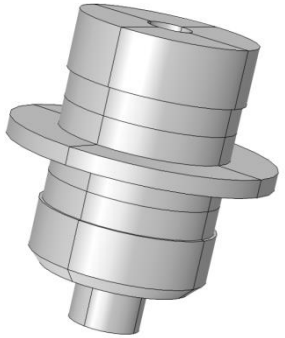


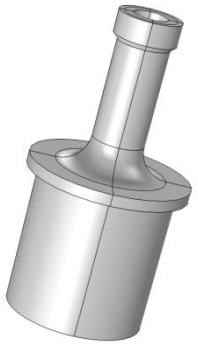
- ▲ Air (60º, v= 1.3 m/s)
- \+ Air (90º, v=1.3 m/s)
- • Ultrasonic vibration by direct contact (P = 100w, air 22º, v= 1m/s)

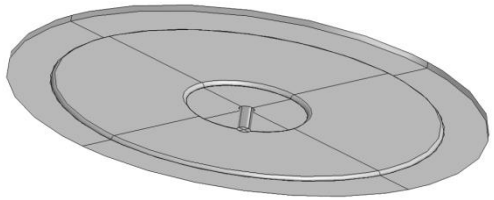


OBJECTIVE

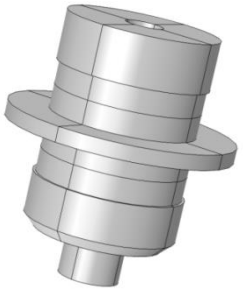


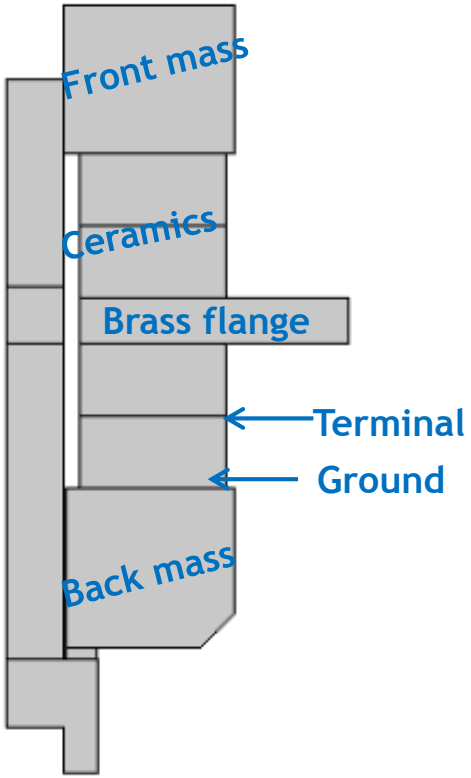






TRANSDUCER DESIGN
LANGEVIN TYPE TRANSDUCER





$$\tan\left(\frac{\omega l_c}{c_c}\right)\tan\left(\frac{\omega l_i}{c_i}\right)=\frac{\rho_c c_c A_c}{\rho_i c_i A_i}$$

(Neppiras 1973)

Multiphysics simulation:

- Electrostatic.- Ceramic stack (piezoelectric materials PZT 802)

- Solid Mechanics.- Ceramics, back and front masses, brass flange and bolt).

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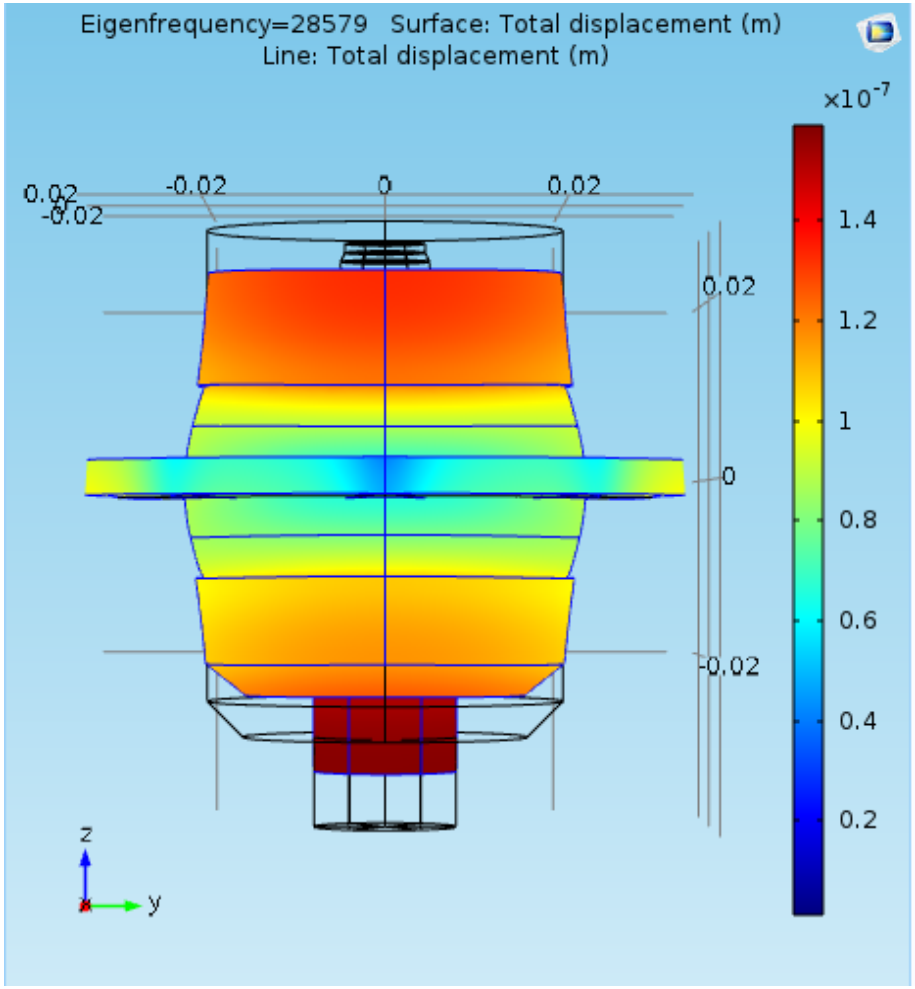
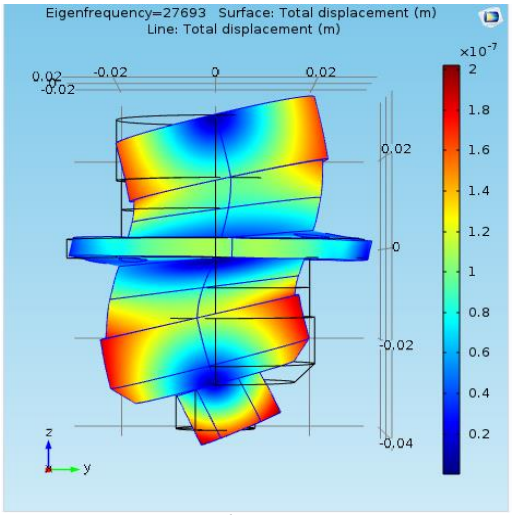
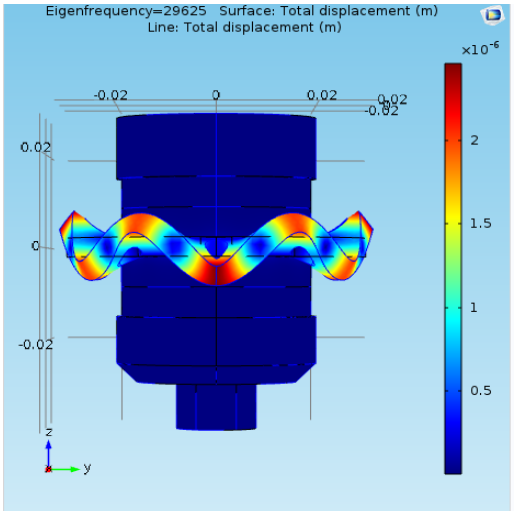


28579 Hz



27693 Hz



29625 Hz

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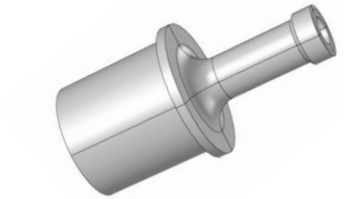
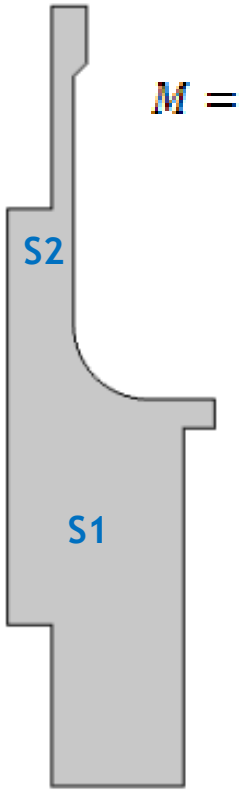
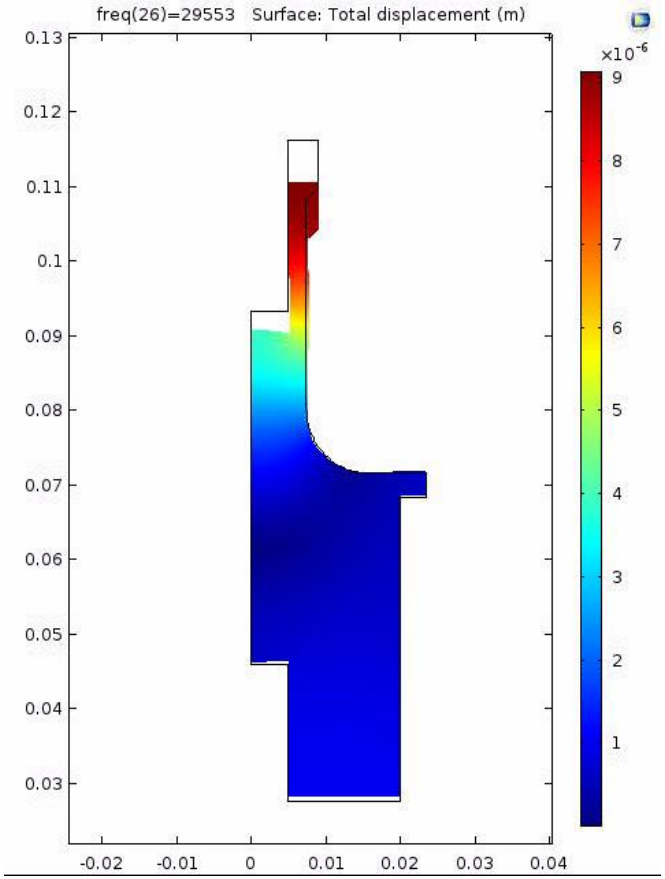
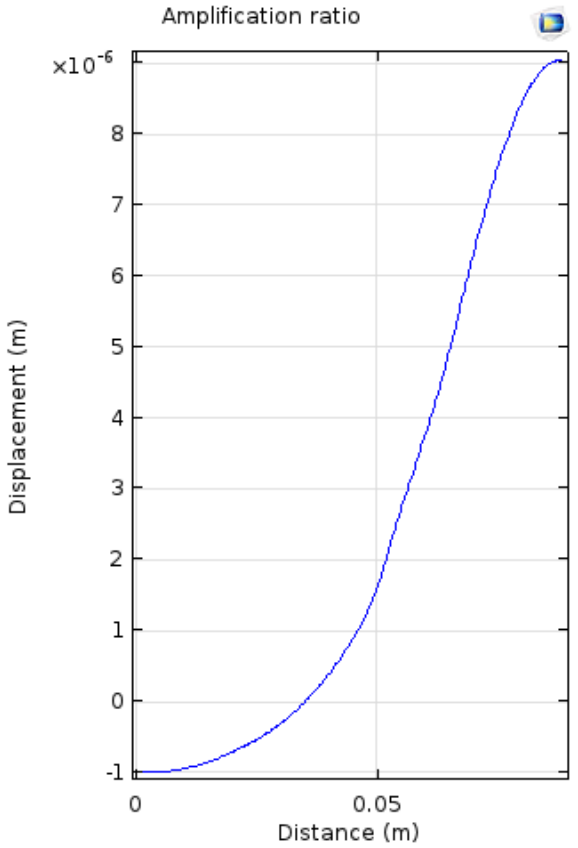
TRANSDUCER DESIGN
MECHANICAL AMPLIFIER



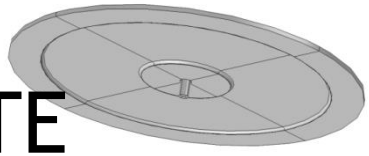


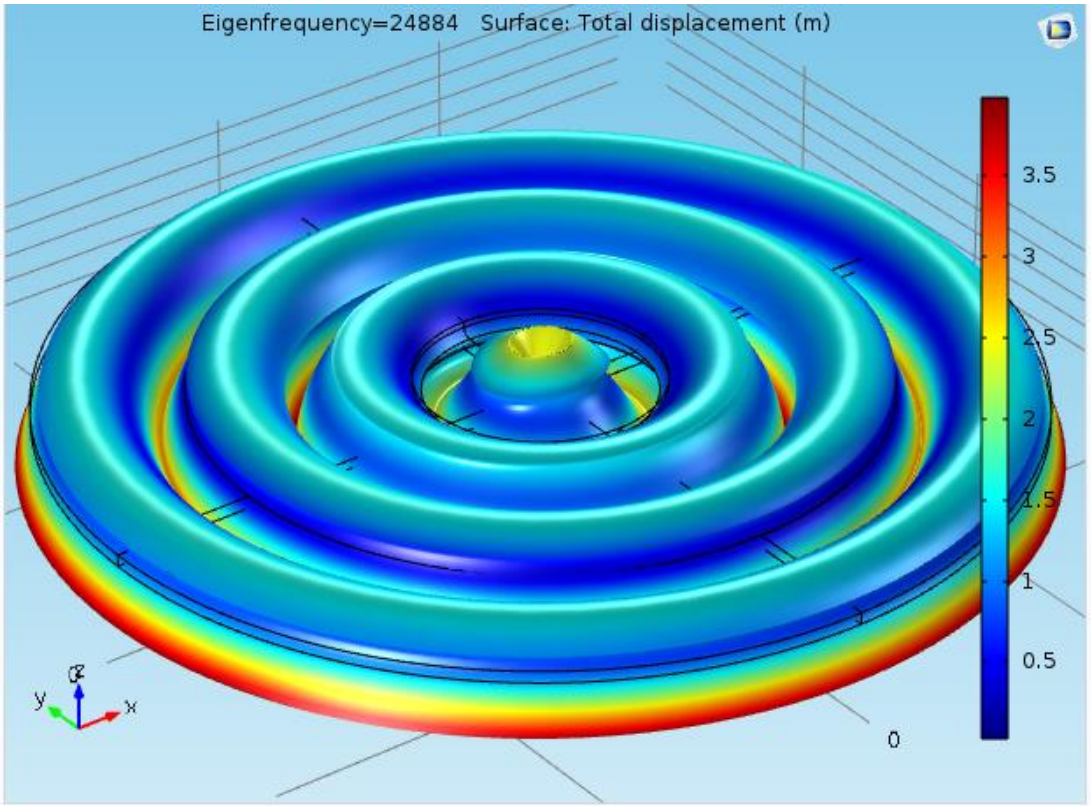
$$M = \frac{S_1}{S_2} = \left(\frac{D_1}{D_2}\right)^2$$

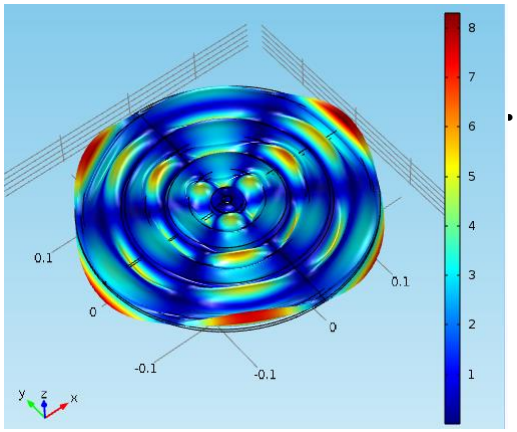


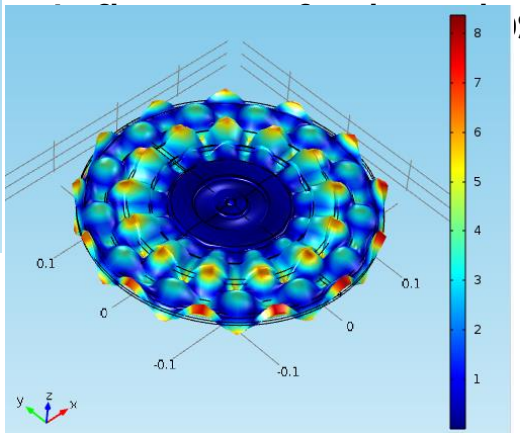


TRANSDUCER DESIGN
STEPPED-GROOVED CIRCULAR PLATE









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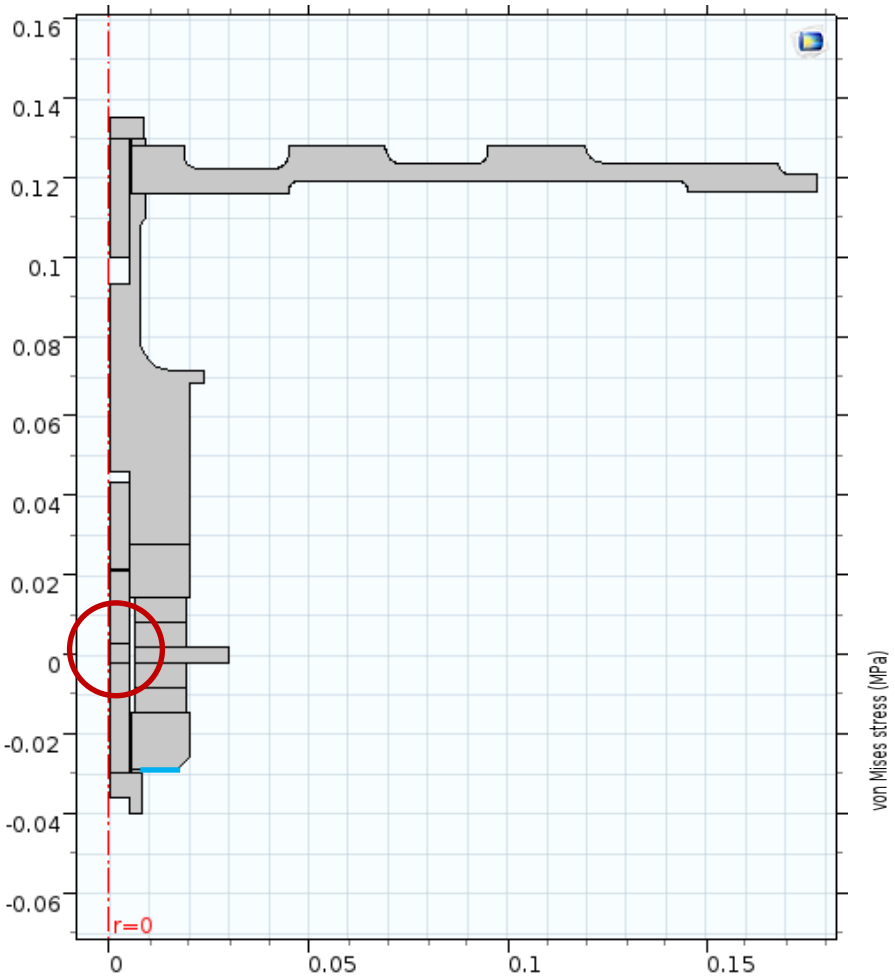
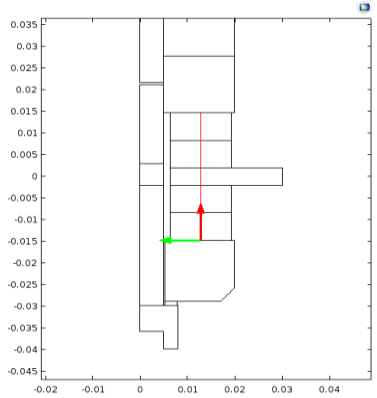
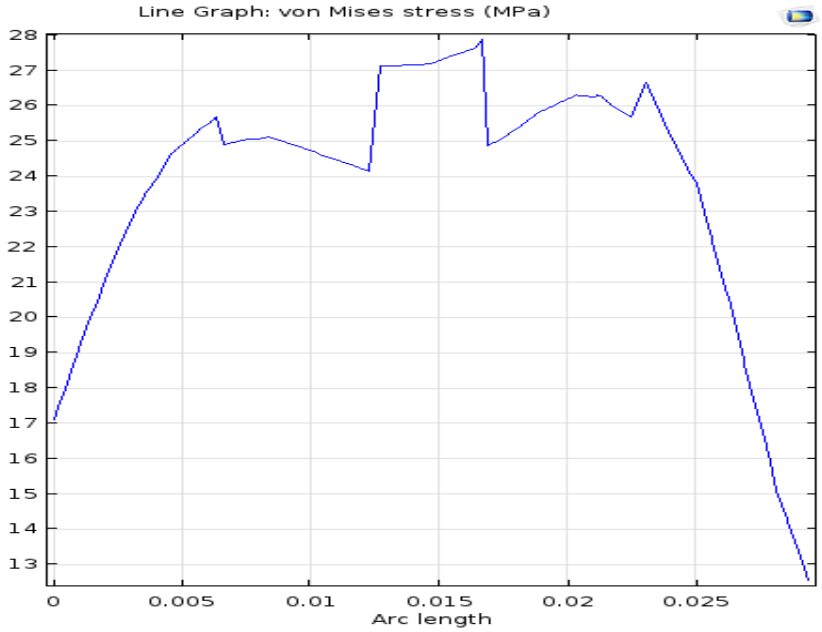
TRANSDUCER DESIGN STATIONARY STUDY







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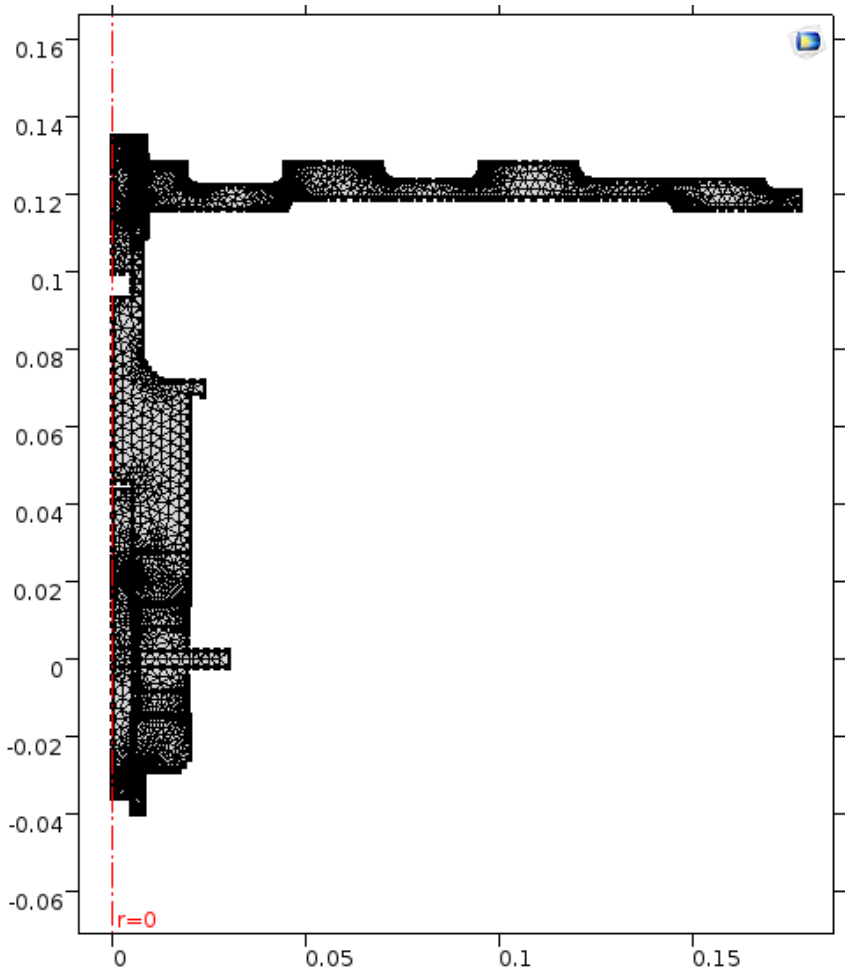
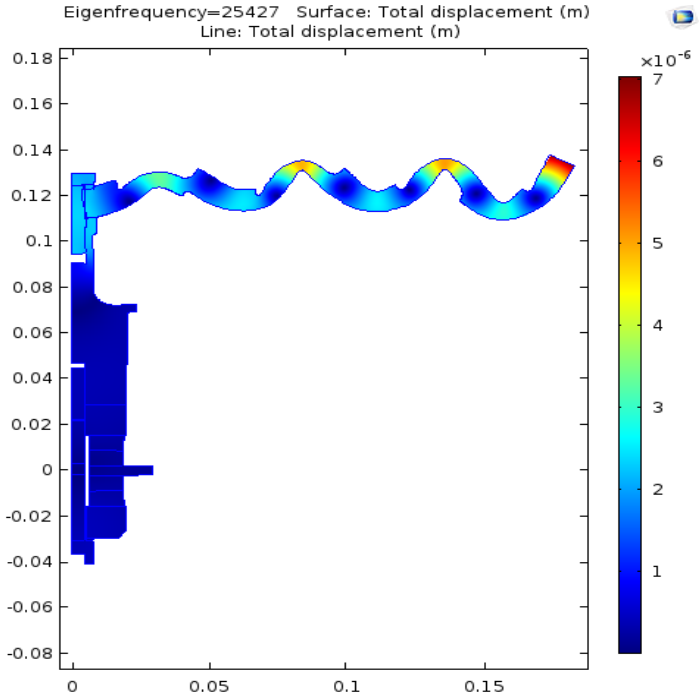
TRANSDUCER DESIGN EIGENFREQUENCIES



9452	14116	20959	27268
10866	14283	24070	29235
12169	15376	24125	32669
12871	15585	**25427**	33496



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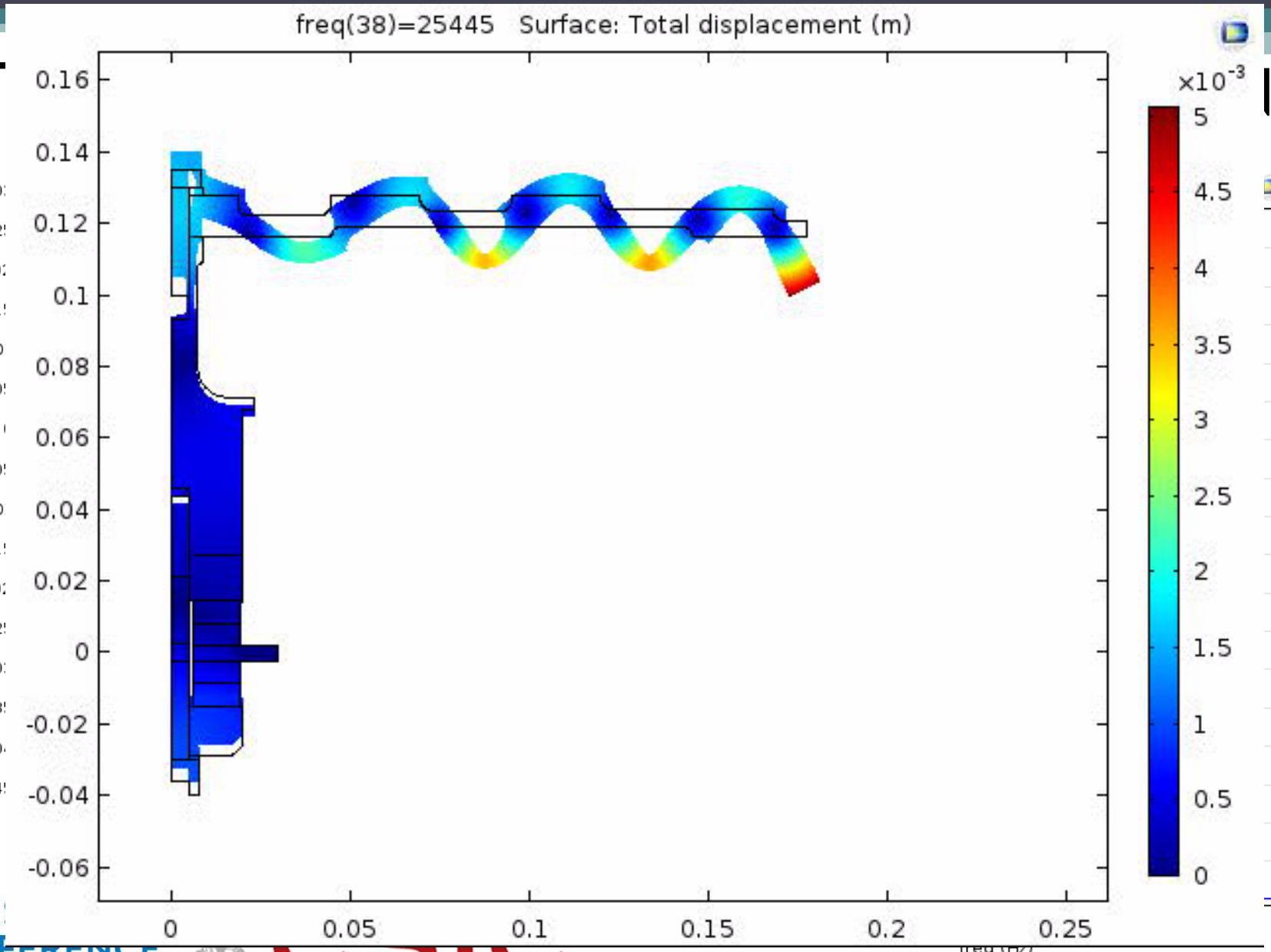
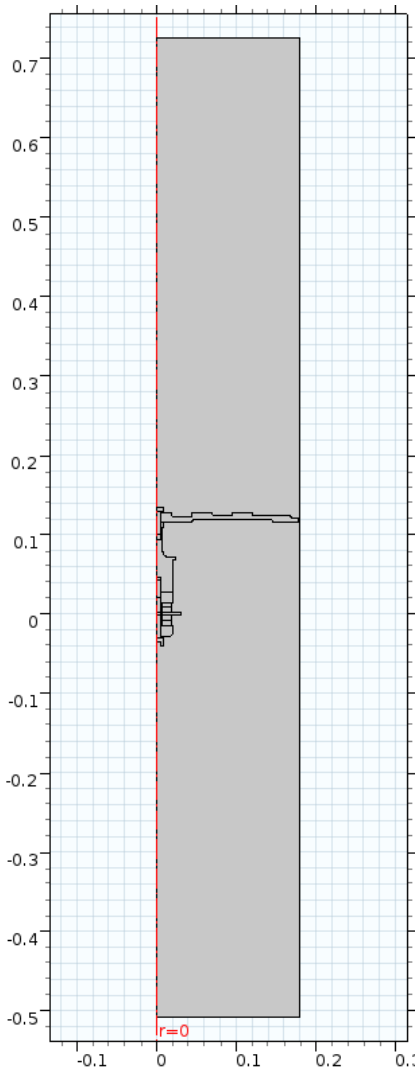




ULTRASONIC FIELD DEHYDRATION CHAMBER

Multiphysics simulation:

- Electrostatic.- Ceramic stack (piezoelectric materials PZT 802)

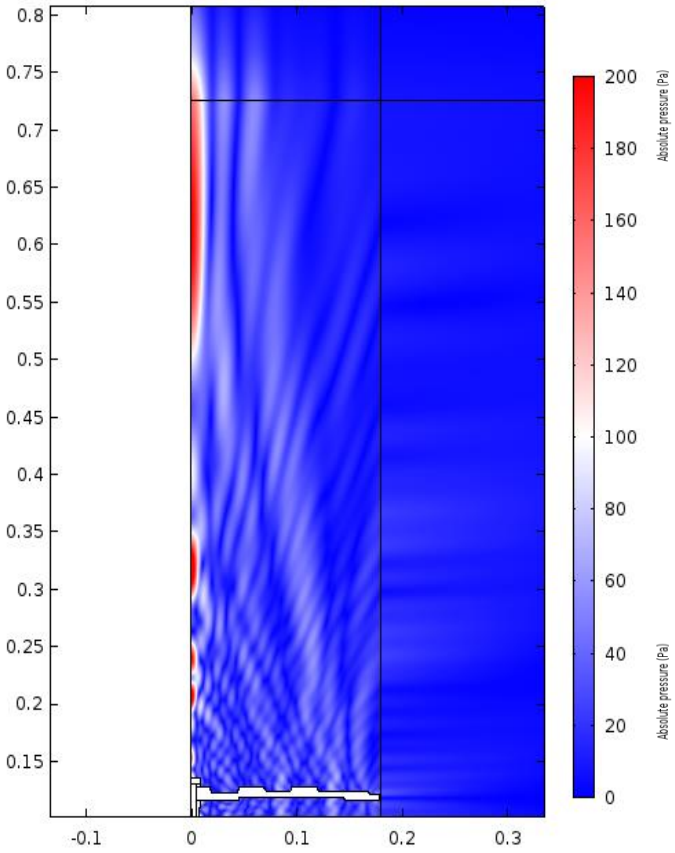
- Solid Mechanics.- Transducer (PZT-802, steel and titanium alloy).

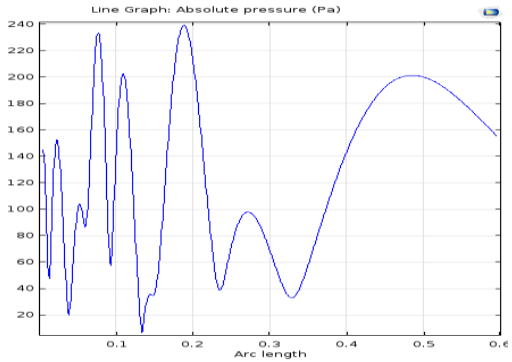
- Pressure Acoustics.- Air at 20ºC (considered as a thermo viscous fluid).

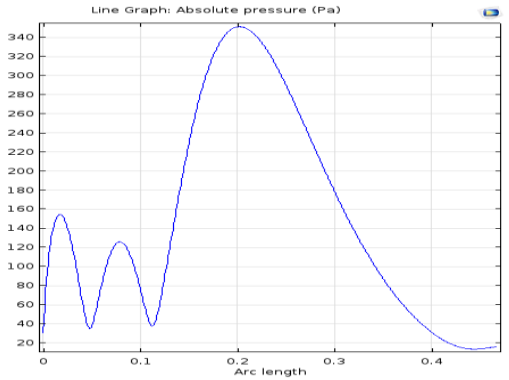
Sound hard boundaries.
Free triangular mesh with maximum element size λ/16

ULTRASONIC FIELD FREE FIELD (PML)

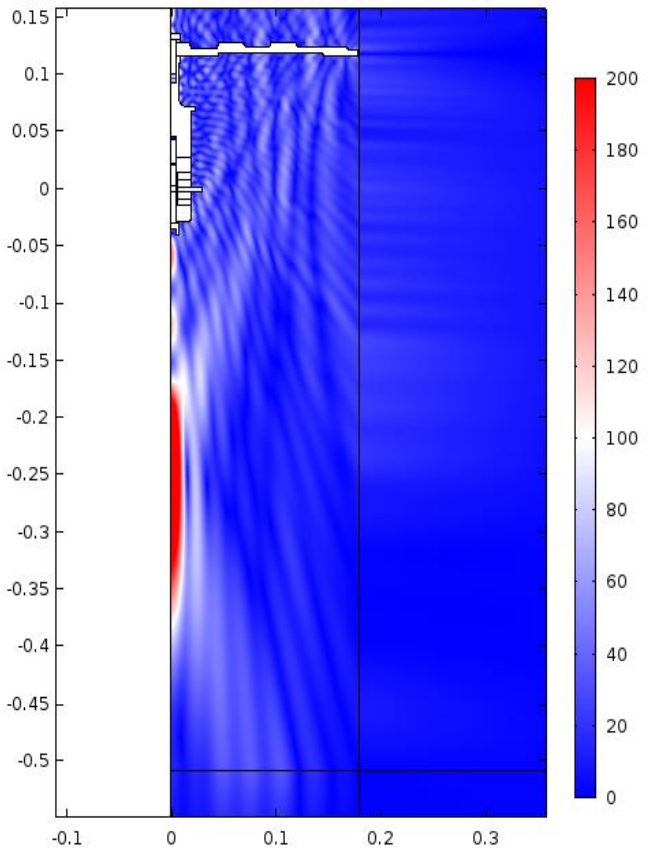
Coherent side





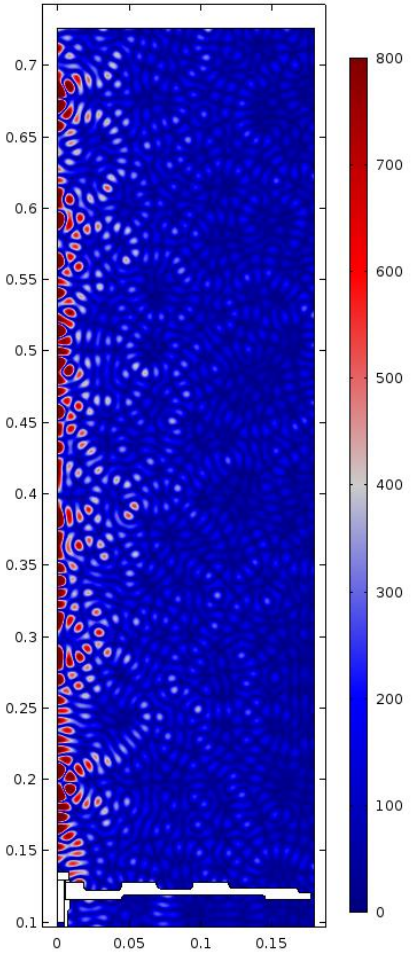


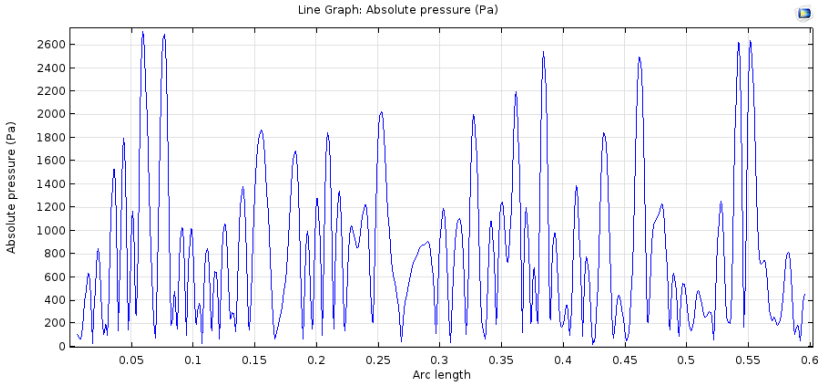
Focused side

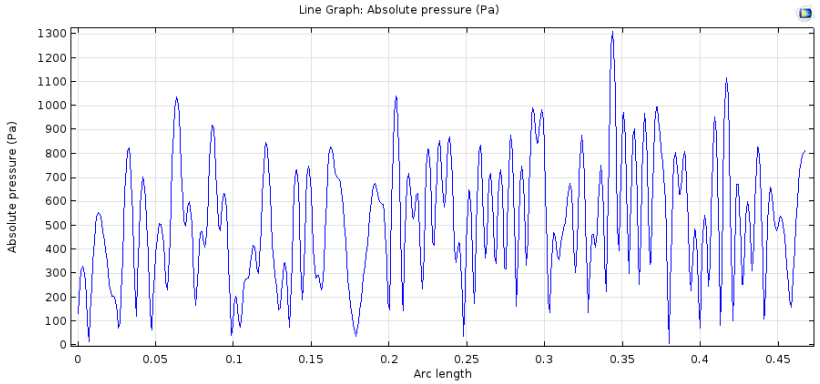


ULTRASONIC FIELD
ULTRASONIC CHAMBER

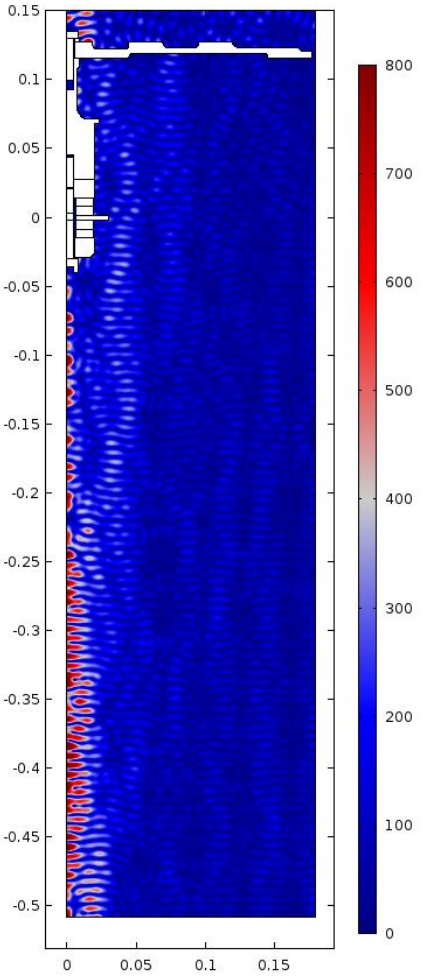
Coherent side







Focused side



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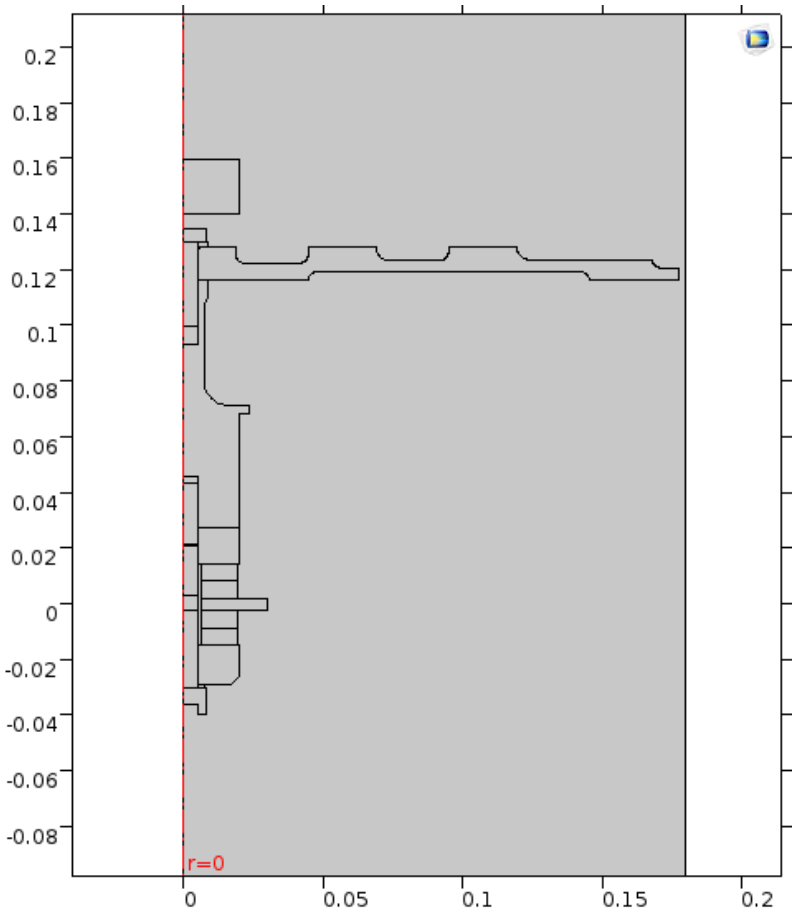
DEHYDRATION KINETICS



Porous materials: porosity, flow resistance, density...

Potato sample 20x20 mm

Fluid element. Effective density and sound speed

Effective density (kg/m^3)	Effective sound speed (m/s)
$1.21 + i\ 1.15\ 10^8$	$0.176 + i\ 0.176$

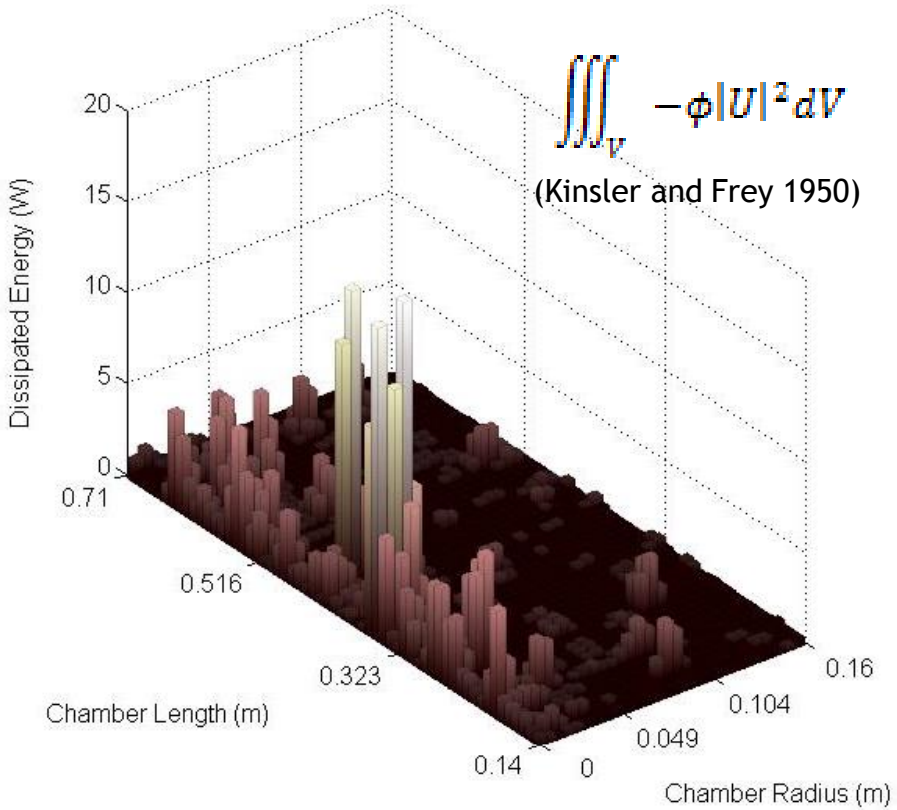
(Morse and Ingard 1968)

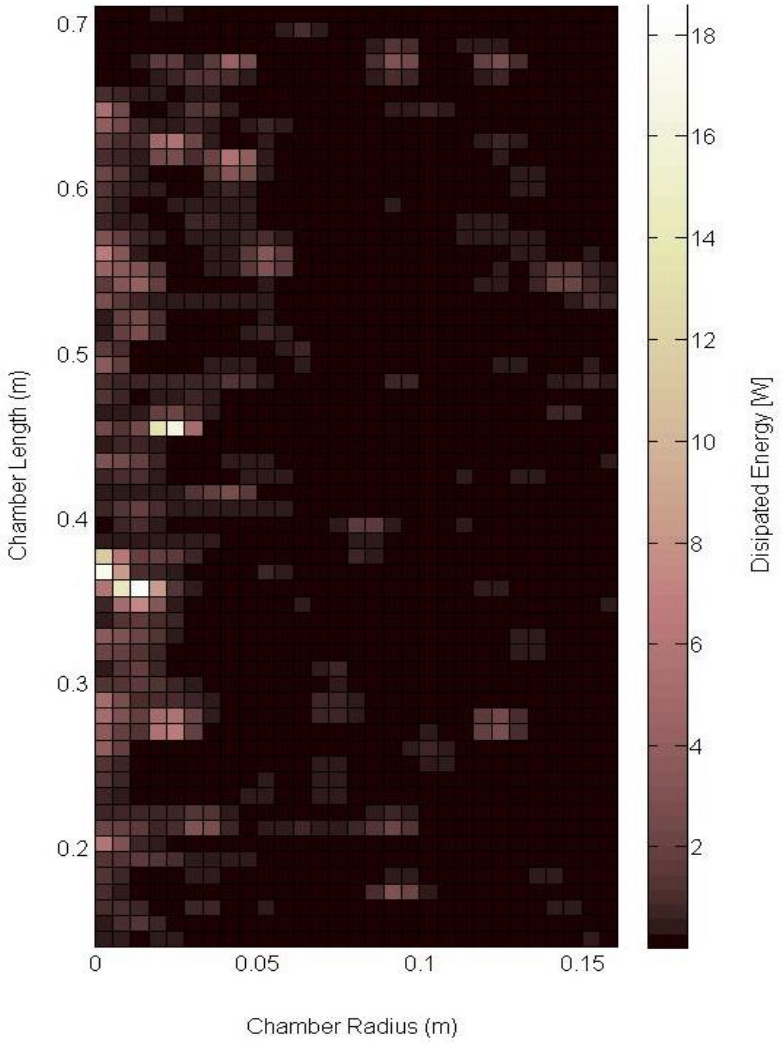
Free triangular mesh with maximum element size $\lambda/16$

DEHYDRATION KINETICS
ENERGY ABSORPTION ANALYSIS

$$\iiint_V -\phi|U|^2 dV$$

(Kinsler and Frey 1950)





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CONCLUSION AND FUTURE RESEARCH LINES

A numerical study of a food dehydration system assistedby power ultrasound has been made.

Including:

- High power ultrasonic transducer design
- Acoustic field simulation
- Food samples behaviour

Future research lines: study the non-linear propagation and other configurations.

http://www.itefi.csic.es

THANK YOU VERY MUCH

FOR YOUR ATTENTION

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