Considerations regarding the design of a power ultrasonic transducer with flat rectangular plate

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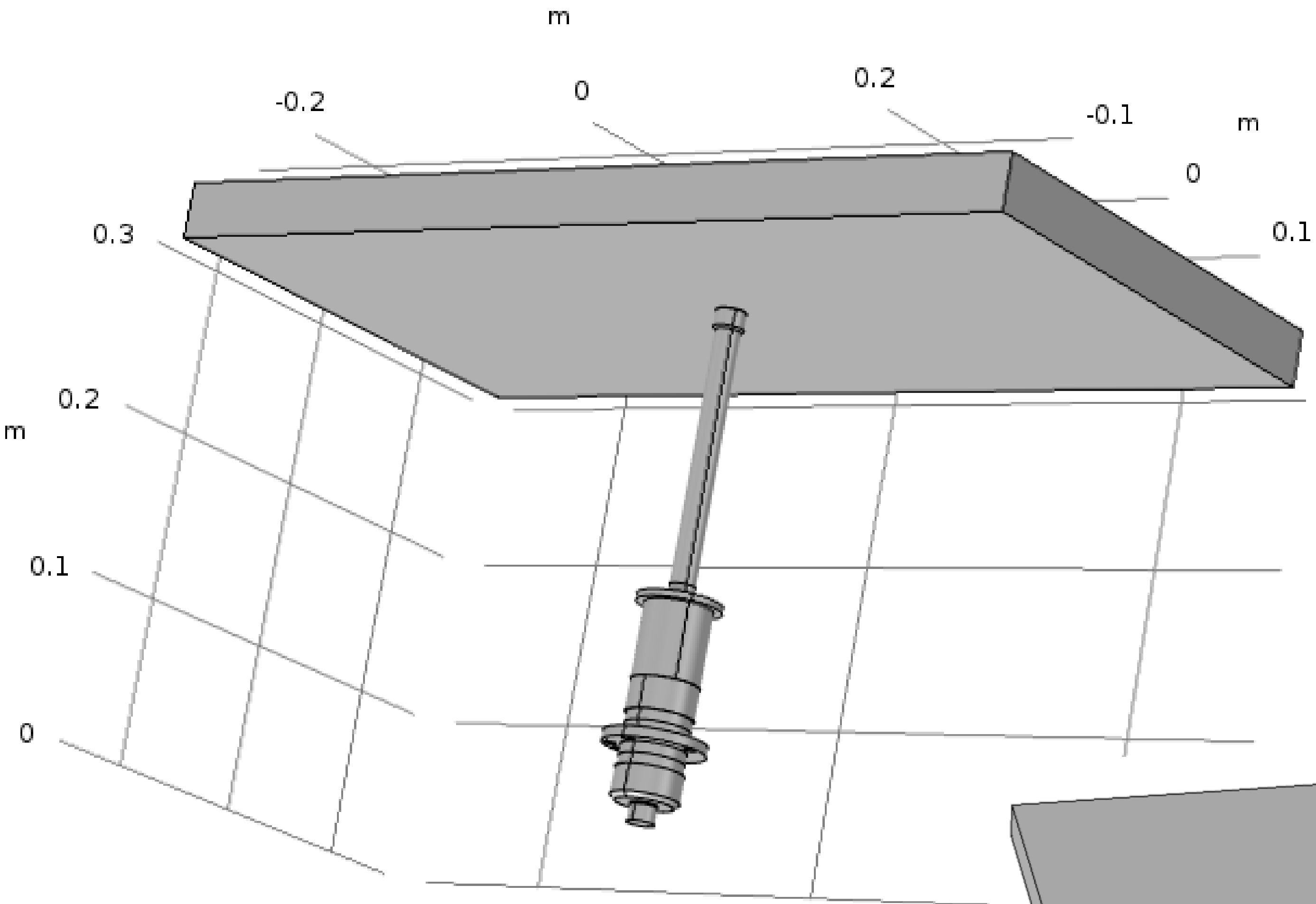
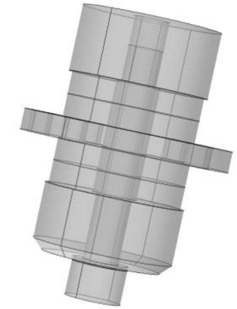
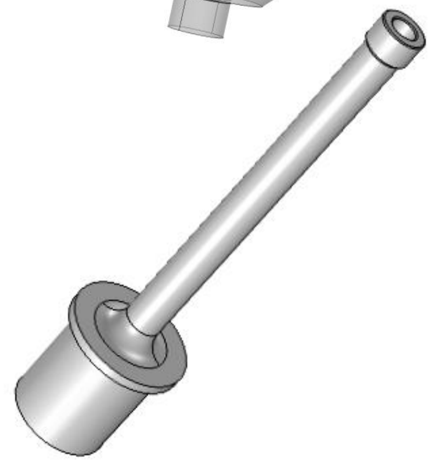
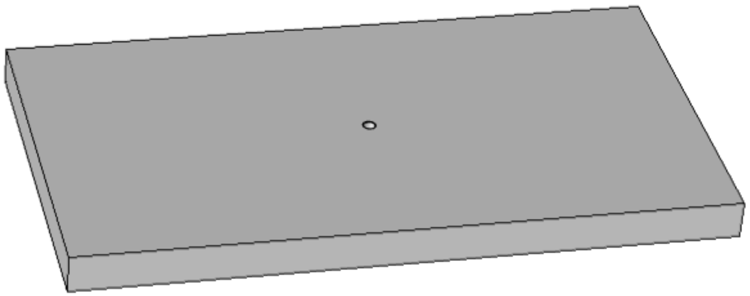
HPU TRANSDUCER WITH RECTANGULAR RADIATOR

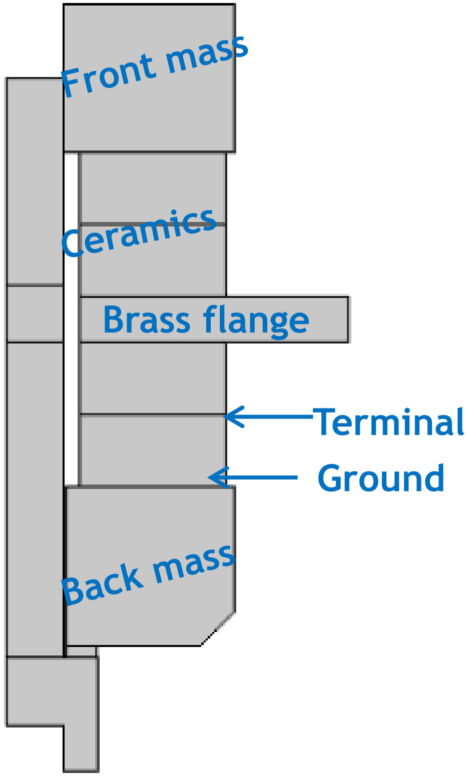


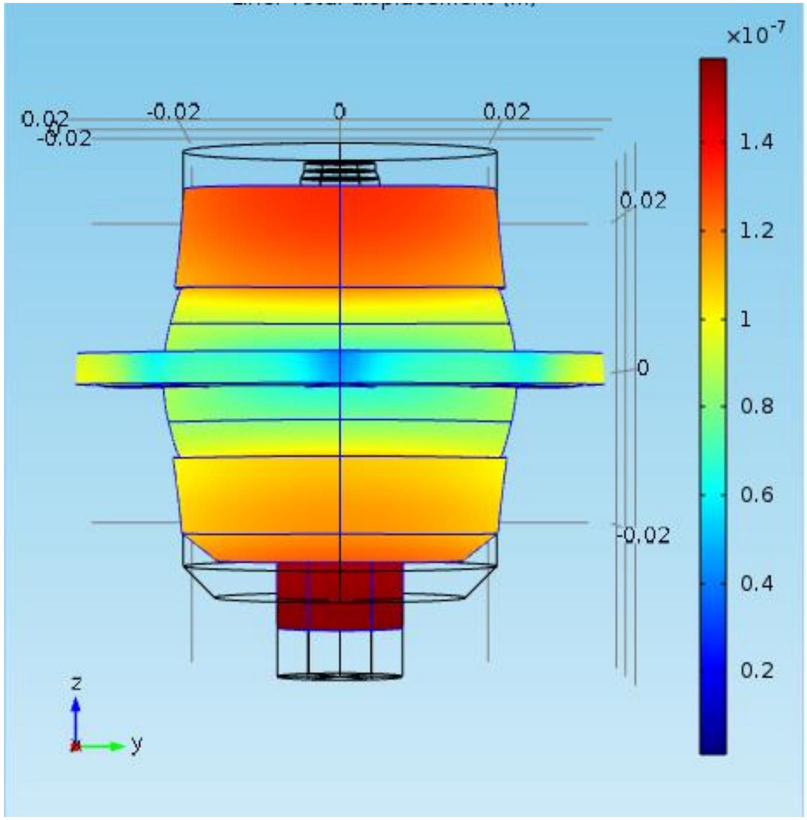


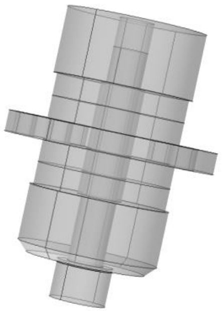




TRANSDUCER DESIGN
LANGEVIN TYPE TRANSDUCER

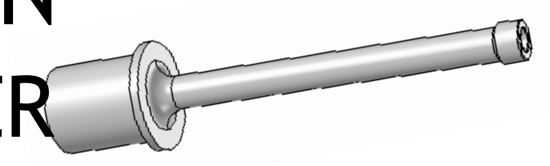


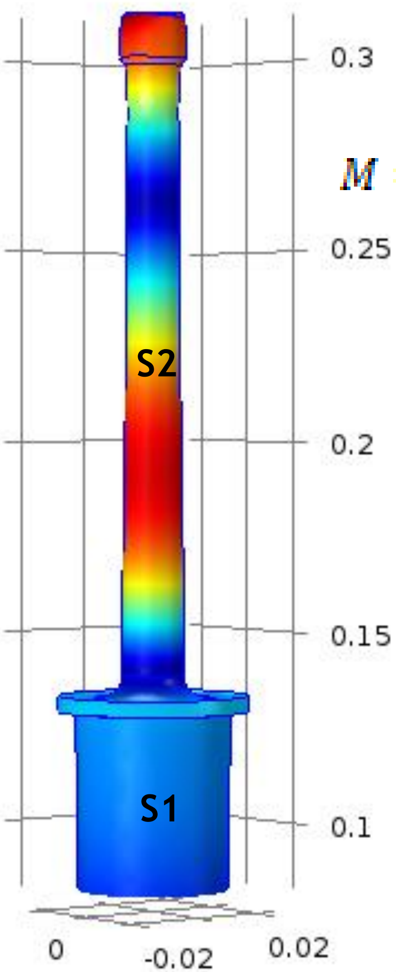




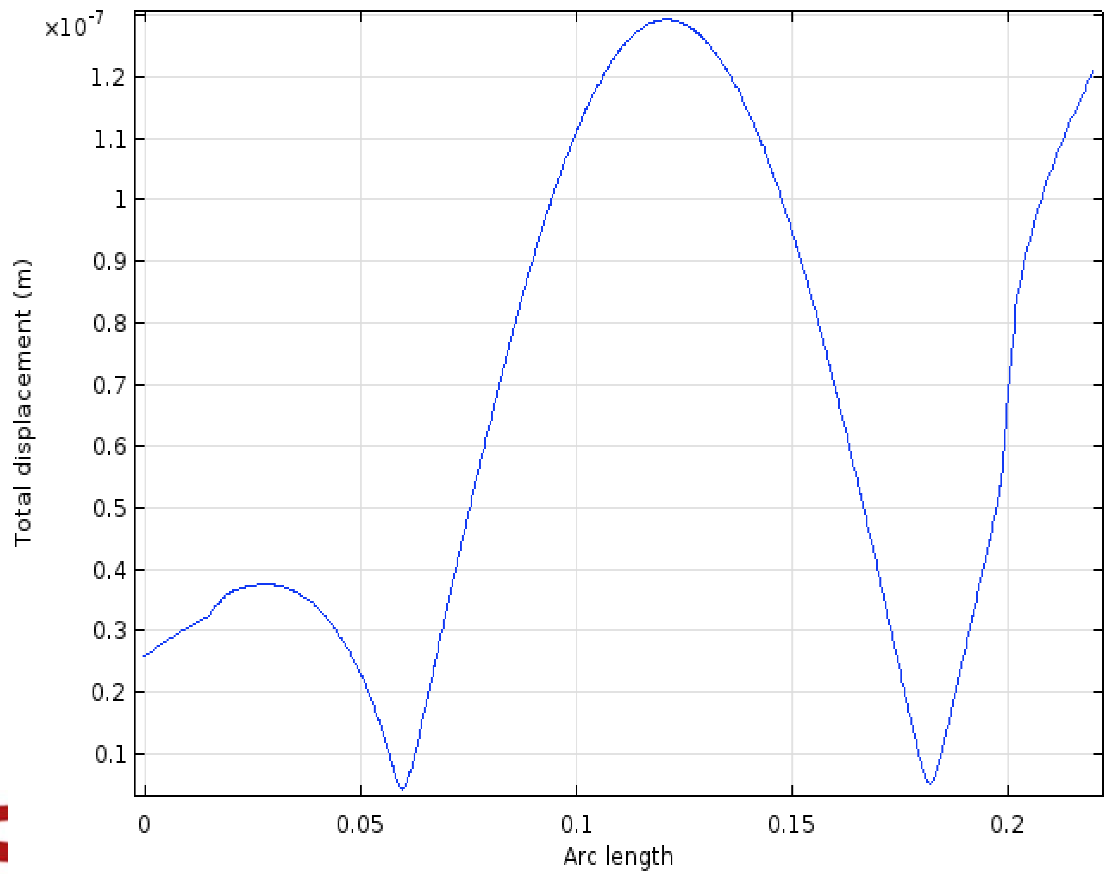
TRANSDUCER DESIGN

MECHANICAL AMPLIFIER





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



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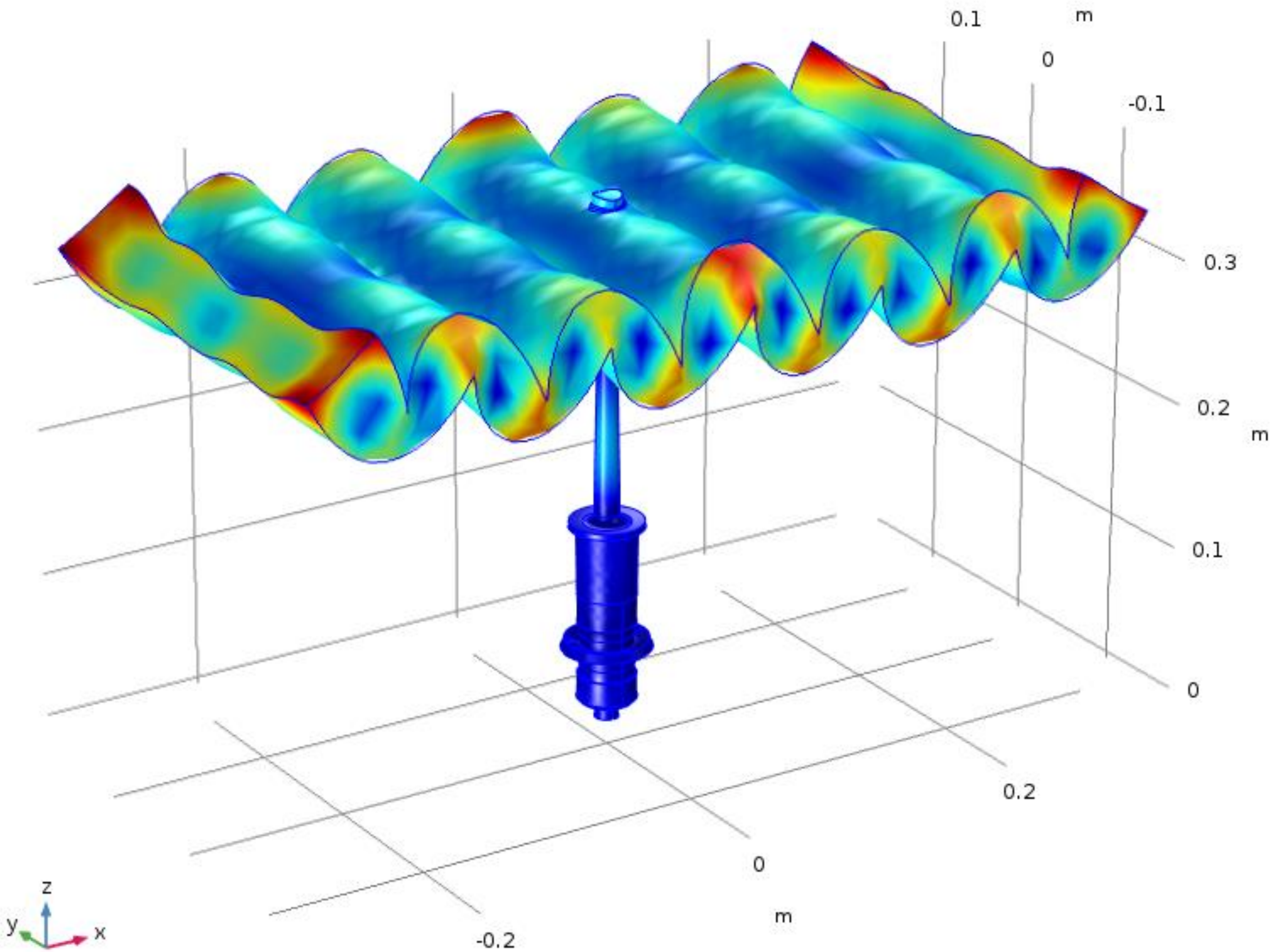
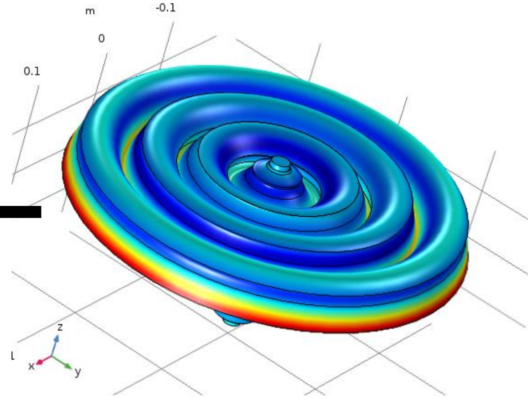
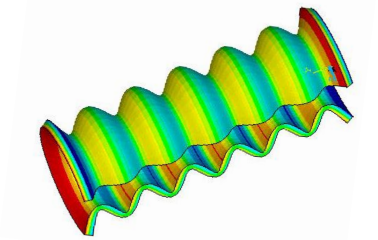


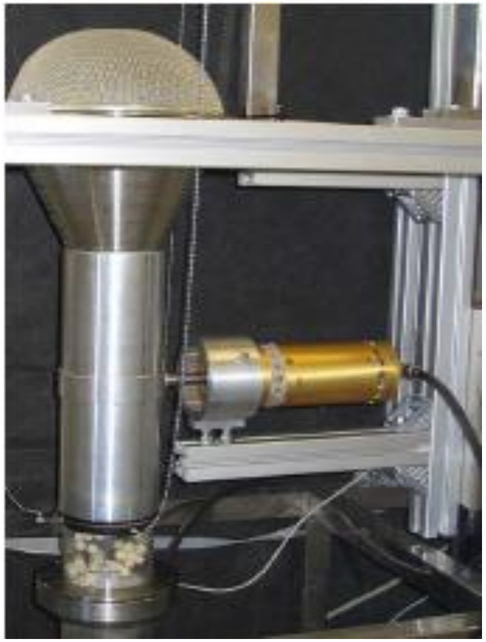
INDUSTRIAL APPLICATIONS

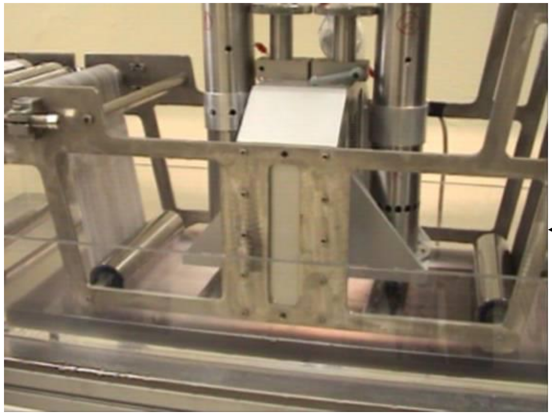
Ultrasonic defoaming

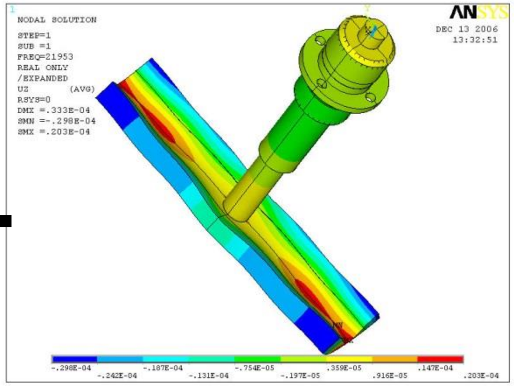


Mass transfer enhancement in food drying



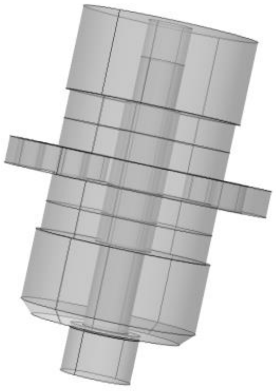






US system for textile washing

PRESTRESS SIMULATION



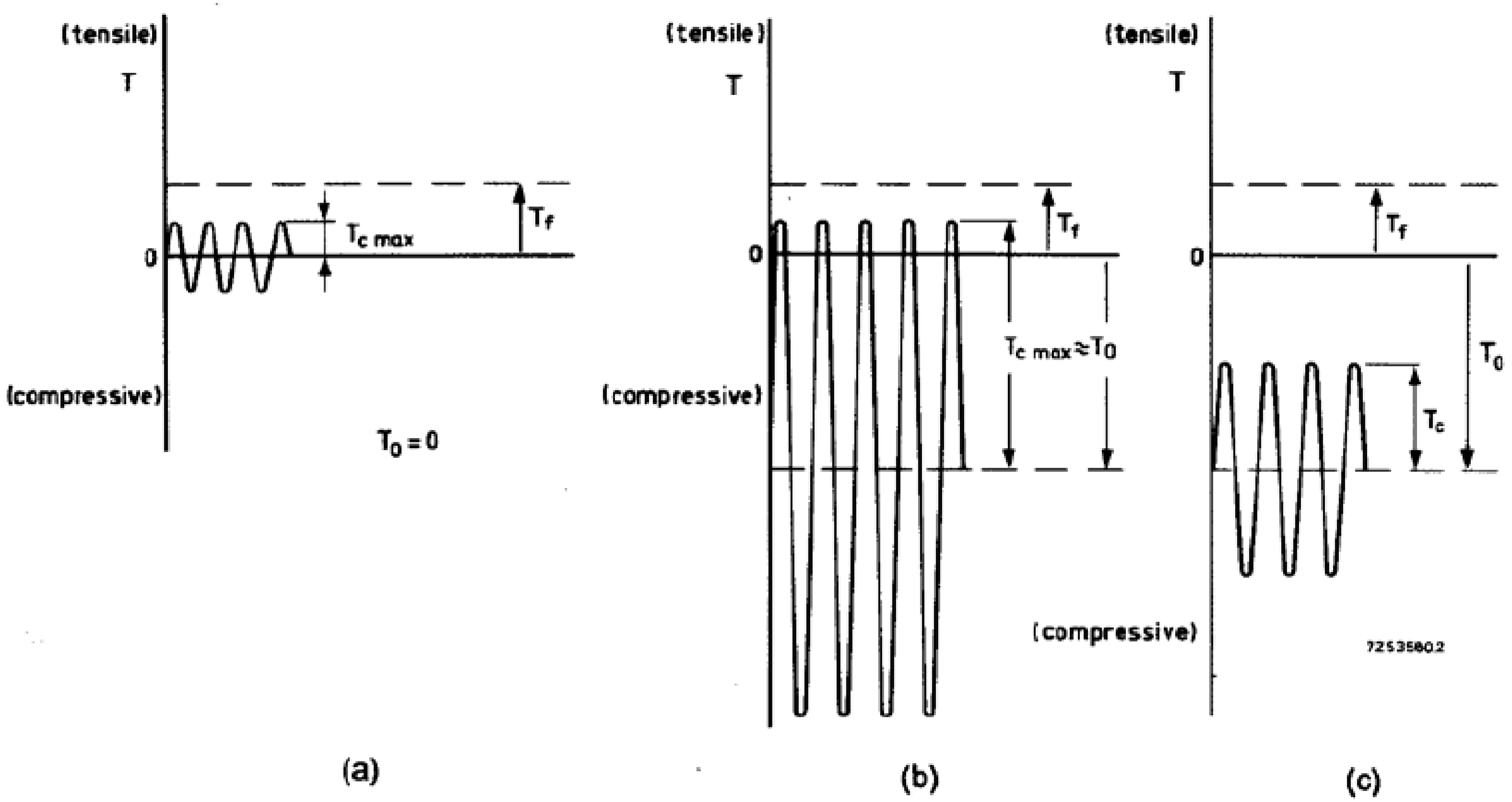
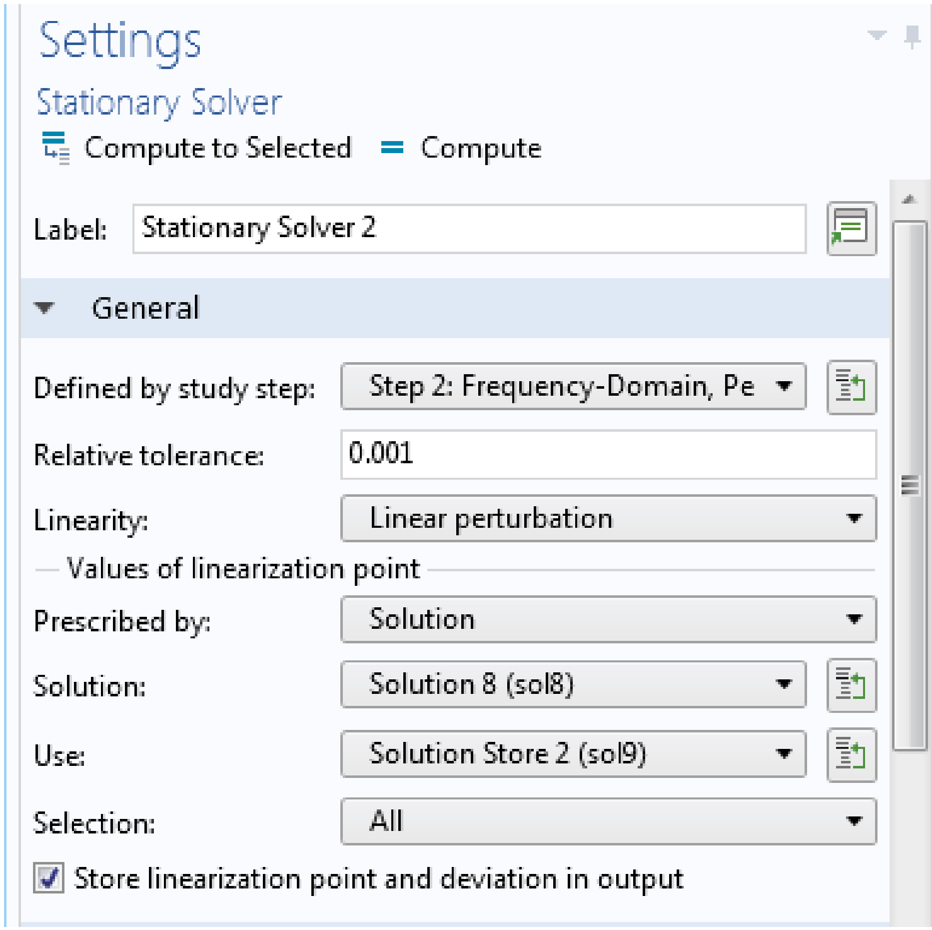
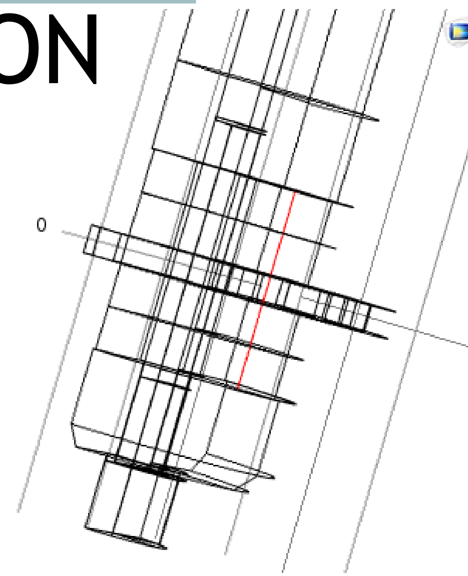


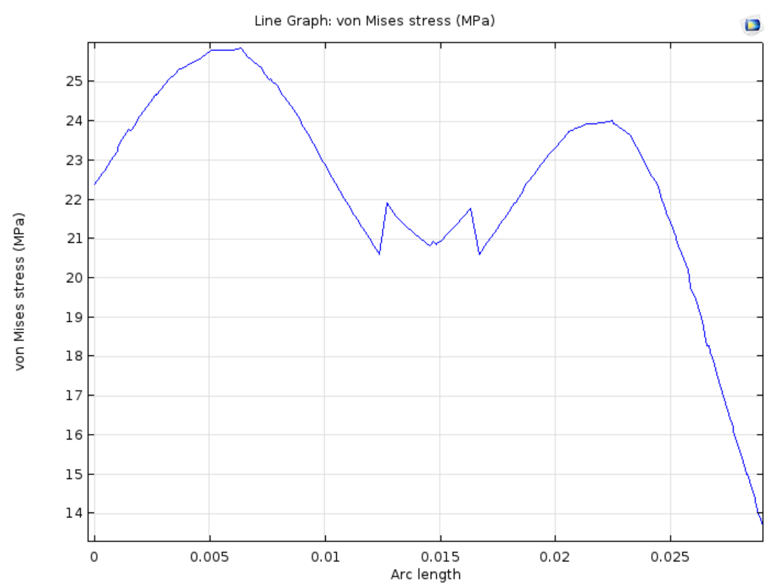
Fig.6.7 Fatigue strength T_f pre-stress T_o and maximum permissible stress amplitude $T_{c\,max}$ in the centre of the transducer; (a) without pre-stress, $T_{c\,max}$ small (T_c limited by fatigue strength of ceramic or bonds); (b) with pre-stress, $T_{c\,max} = T_o$ (T_c limited by fatigue strength of bolts)

Source: http://www.morganelectroceramics.com/pzbook.html

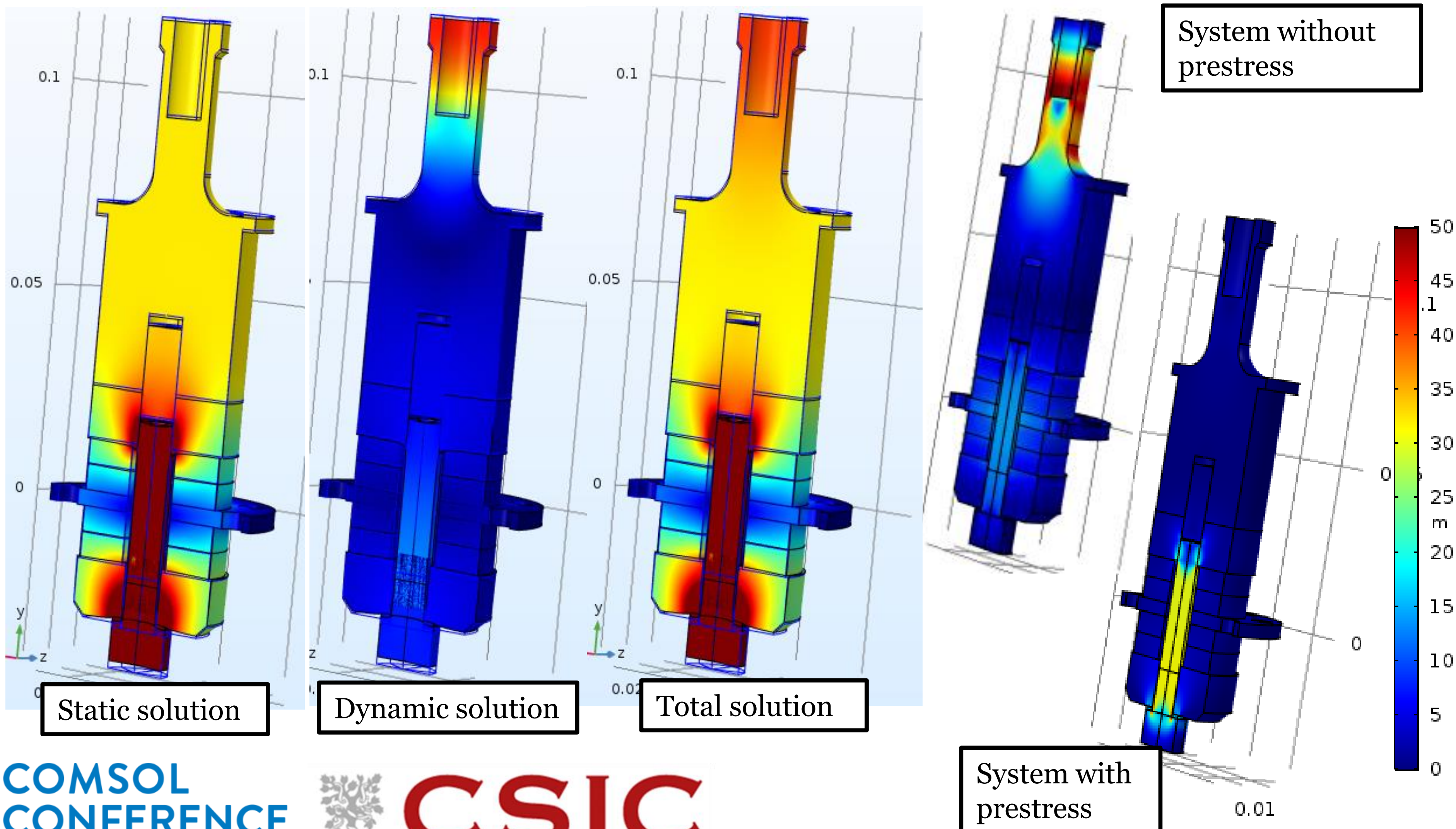
PRESTRESS SIMULATION







PRESTRESS SIMULATION



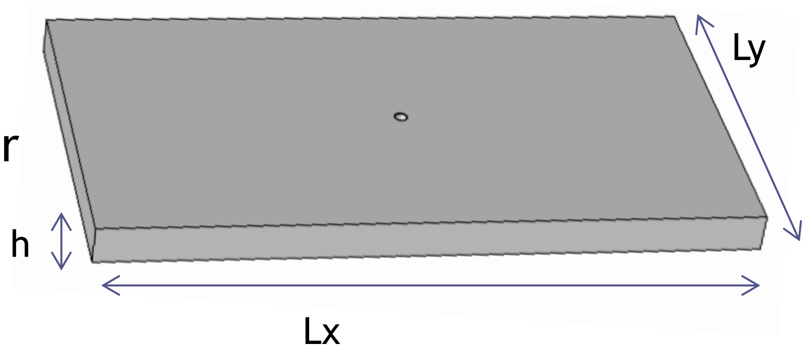
$${f_{m,n}}^2 = \frac{h^2}{4.86\rho}\left[\frac{D_x}{{L_x}^4}\left(\frac{2m-1}{2}\right)^4 + \frac{D_y}{{L_y}^4}\left(\frac{2n-1}{2}\right)^4\right] + m^2 n^2 f_{1,1} \qquad (1)$$

VIBRATION OF RECTANGULAR PLATES

$${f_{m,n}}^2 = \frac{h^2}{4.86\rho}\left[\frac{D_x}{{L_x}^4}\left(\frac{2m-1}{2}\right)^4 + \frac{D_y}{{L_y}^4}\left(\frac{2n-1}{2}\right)^4\right] + +m^2 n^2 f_{1,1}$$

Source: G.W. Caldersmith (1984)

$f_{m,n}$ is the frequency where the desired mode happens
m and *n* are the number of nodal lines perpendicular to x and y side, respectively.
L_x, L_y y *h* are the length of x and y sides, and the thickness, respectively.
ρ is the density of the plate.
D_x and D_y are the corrected Young Modulus for dimensions x and y.
$f_{1,1}$ is the first shear mode.
c_l is the sound speed in the plate.



$$f_{m,n}^2 = \frac{h^2}{4.86\rho}\left[\frac{D_x}{L_x^4}\left(\frac{2m-1}{2}\right)^4 + \frac{D_y}{L_y^4}\left(\frac{2n-1}{2}\right)^4\right] + m^2 n^2 f_{1,1} \quad (1)$$

VIBRATION OF RECTANGULAR PLATES

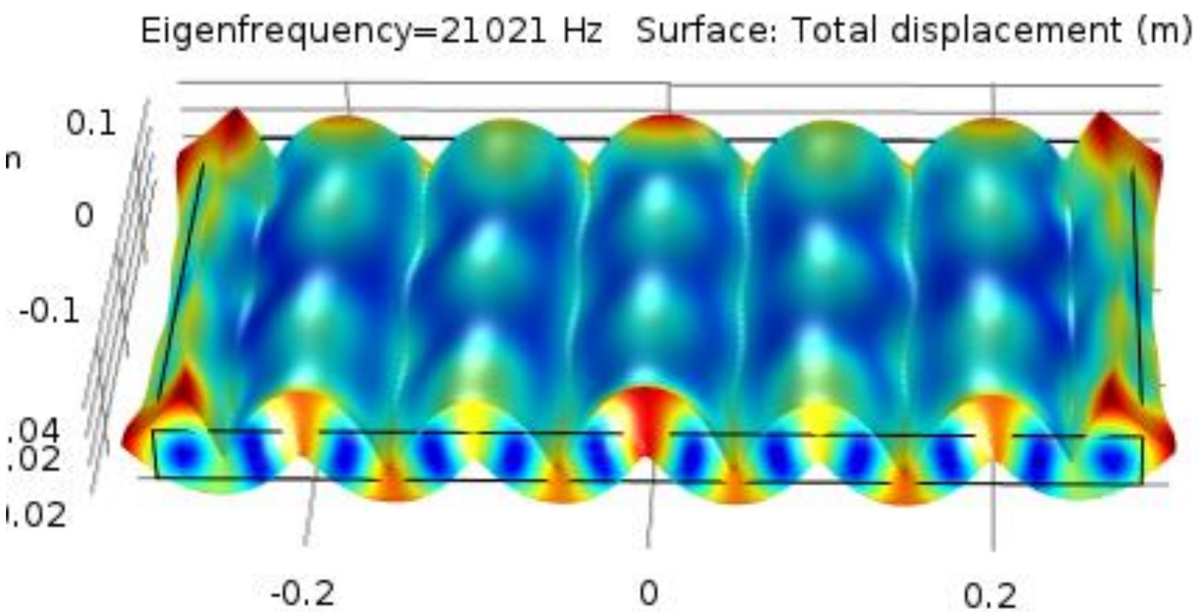


Plate A: Plate with dimensions 570x308x34 mm and an operational mode of 12 nodal lines (NL) in the transversal direction for food dehydration purposes. According to the Caldersmith equation, this mode happens at ***33799 Hz****.*

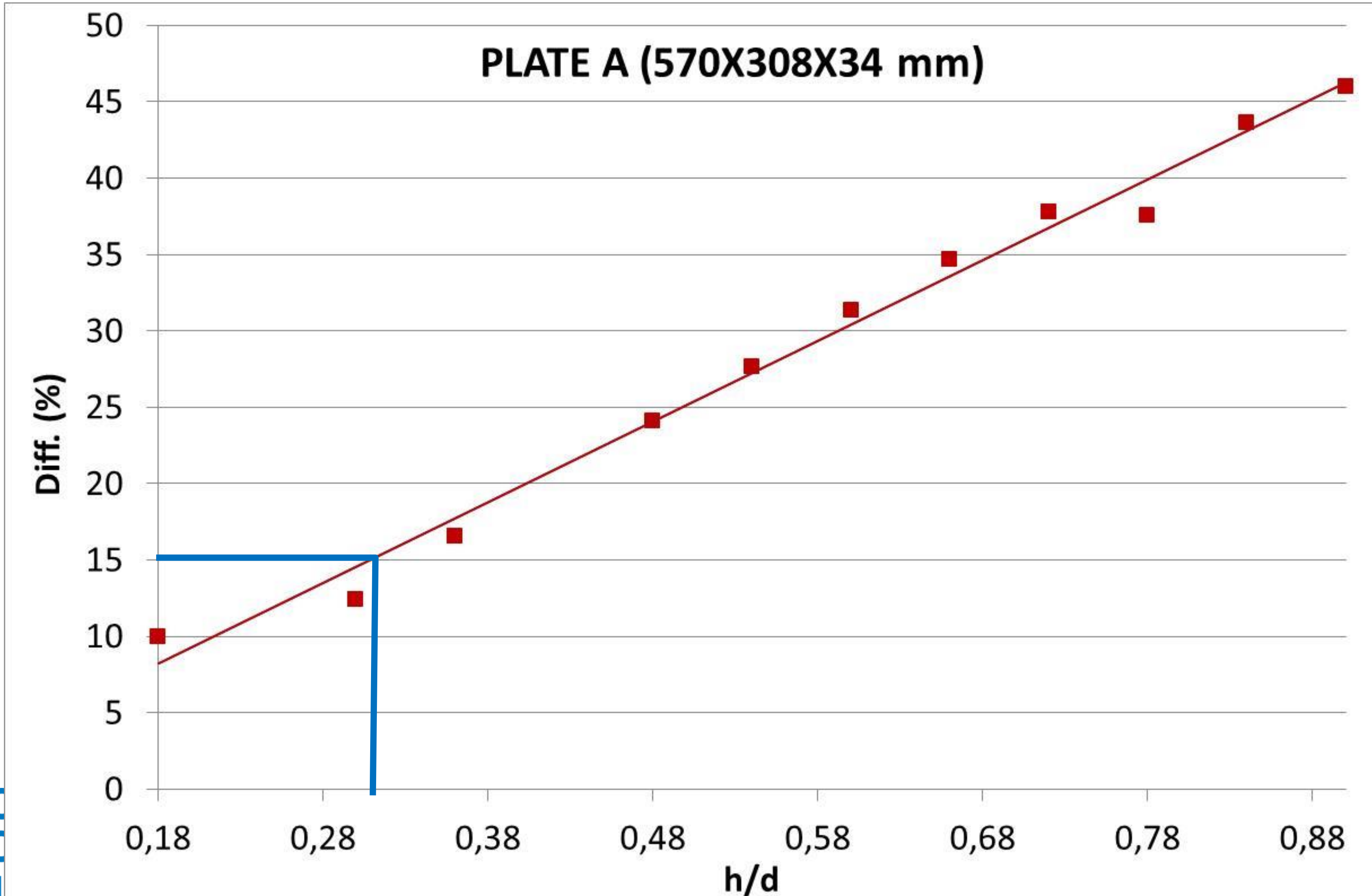
$$f_{m,n}^2 = \frac{h^2}{4.86\rho}\left[\frac{D_x}{L_x^4}\left(\frac{2m-1}{2}\right)^4 + \frac{D_y}{L_y^4}\left(\frac{2n-1}{2}\right)^4\right] + m^2n^2 f_{1,1} \qquad (1)$$

VIBRATION OF RECTANGULAR PLATES

m	fr (Theoretical)	fr (numerical)	Diference	Diff (%)	d (distance between NL)	h/d
3	1612.20	1450.9	161.30	10	0.190	0.18
4	3138.30	---				
5	5179.80	4538.5	641.30	12	0.114	0.30
6	7733.92	6456.1	1277.82	17	0.095	0.36
7	10799.81	---				
8	14377.16	10908	3469.16	24	0.071	0.48
9	18465.82	13357	5108.82	28	0.063	0.54
10	23065.72	15826	7239.72	31	0.057	0.60
11	28176.82	18412	9764.82	35	0.052	0.66
12	33799.10	21021	12778.10	38	0.048	0.72
13	39932.53	24947	14985.53	38	0.044	0.78
14	46577.12	26252	20325.12	44	0.041	0.84
15	53732.86	29000	24732.86	46	0.038	0.89

$$f_{m,n}^2 = \frac{h^2}{4.86\rho}\left[\frac{D_x}{L_x^4}\left(\frac{2m-1}{2}\right)^4 + \frac{D_y}{L_y^4}\left(\frac{2n-1}{2}\right)^4\right] + m^2n^2 f_{1,1} \qquad (1)$$

VIBRATION OF RECTANGULAR PLATES



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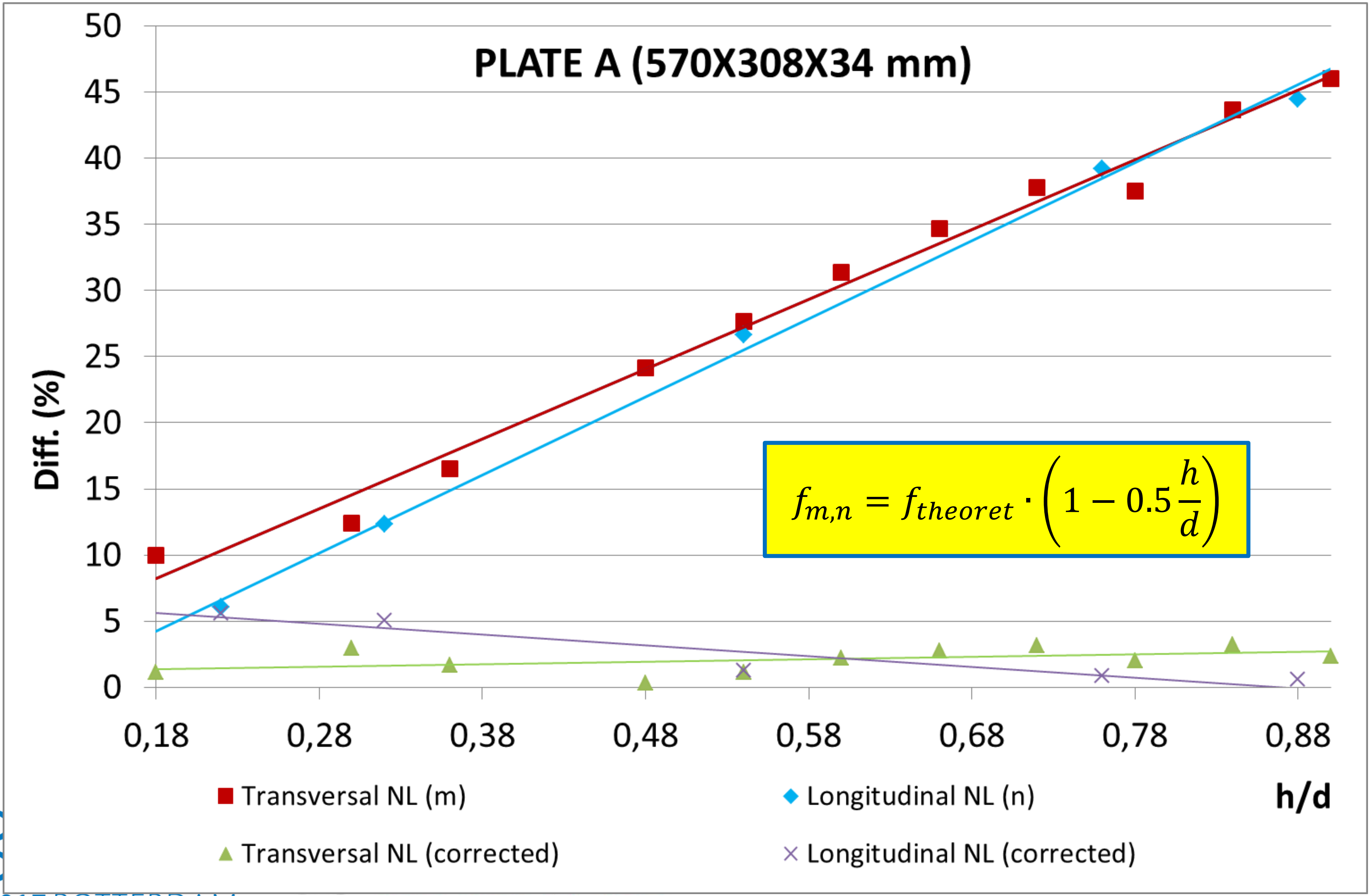
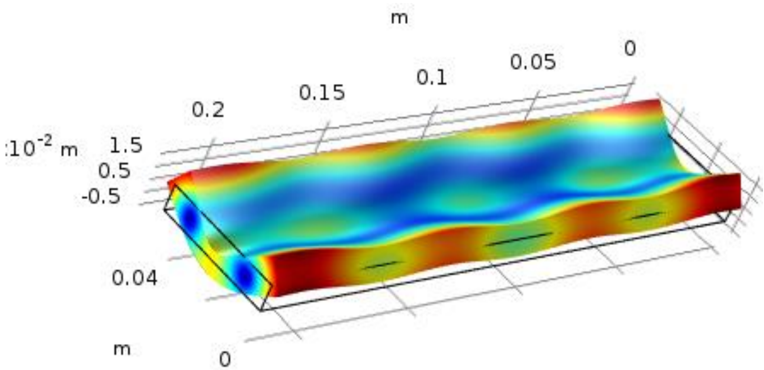
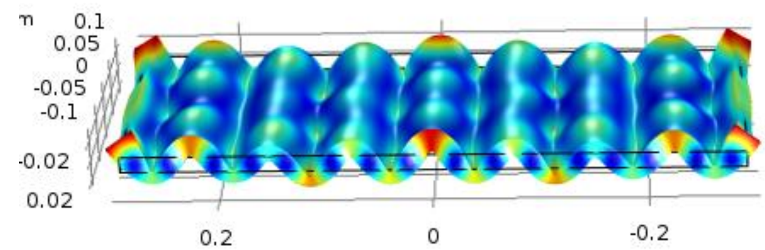


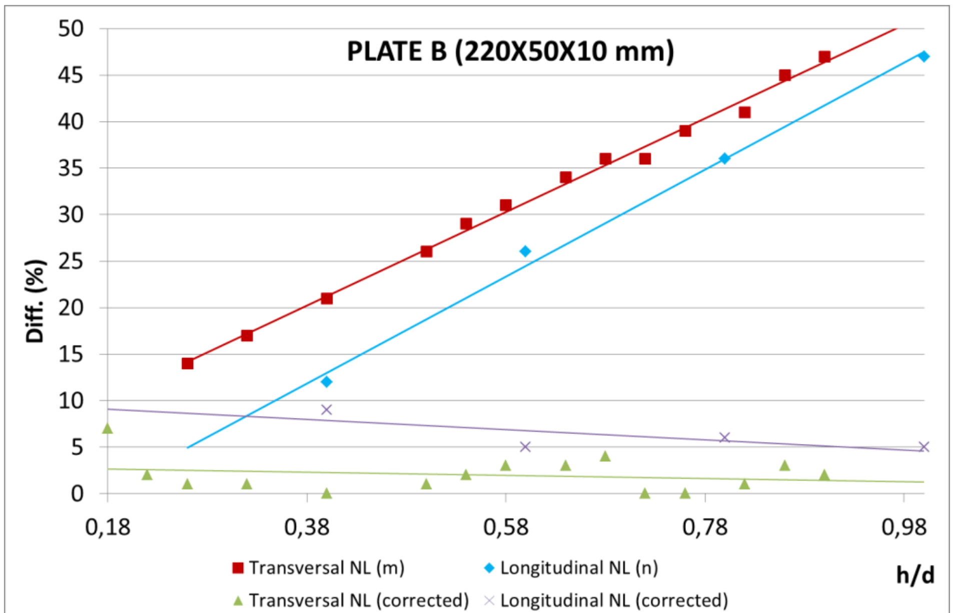
$$f_{m,n} = f_{theoret} \cdot \left(1 - 0.5\,\frac{h}{d}\right)$$

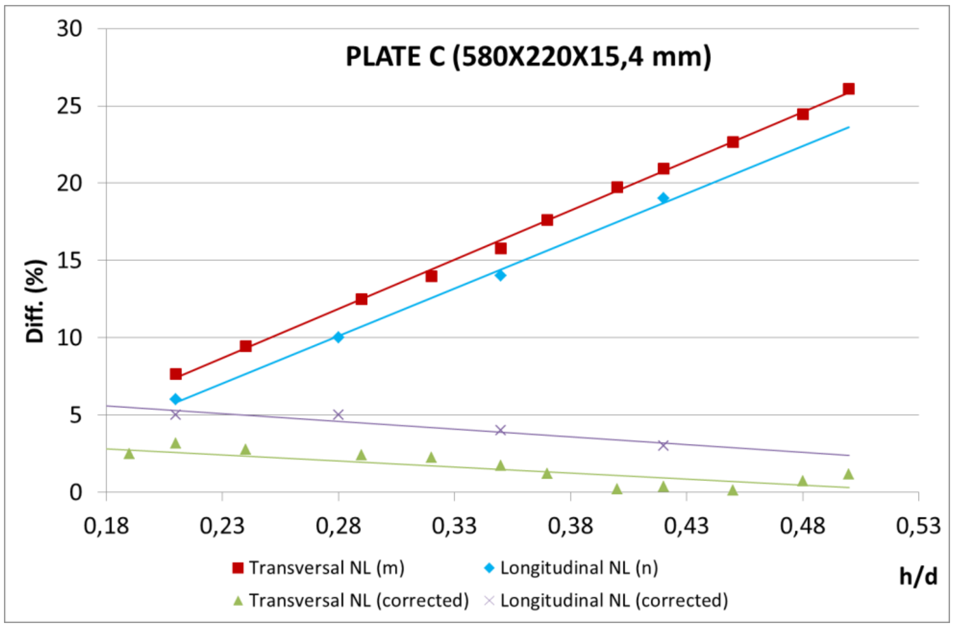
$$f_{m,n}^2 = \frac{h^2}{4.86\rho}\left[\frac{D_x}{L_x^4}\left(\frac{2m-1}{2}\right)^4 + \frac{D_y}{L_y^4}\left(\frac{2n-1}{2}\right)^4\right] + \ldots + m^2 n^2 f_{1,1} \qquad (1)$$

VIBRATION OF RECTANGULAR PLATES









CONCLUSION

The design of power ultrasonic transducers with rectangular radiator for industrial purposes has some aspects to take into account.

The application of a mechanical prestress to the piezoceramics allows higher displacements and a high intensity sound field.

The simulation can be done in a two step study, including the results of the static analysis as an input to the dynamic analysis.

In the study of vibration of plates is important to know when the rectangular radiator is considered as a thin or a thick plate.

When the distance between nodal lines is at least 3 times the thickness, the plate can be considered as a thin plate, and the theoretical method can be used. Otherwise, a correction of the equation is proposed.

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THANK YOU VERY MUCH

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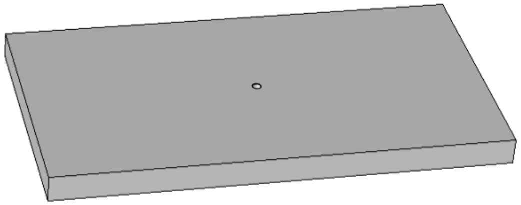
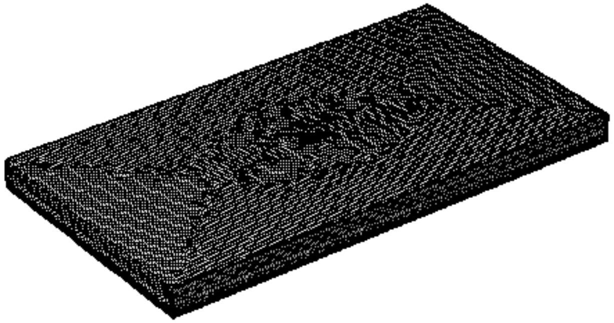
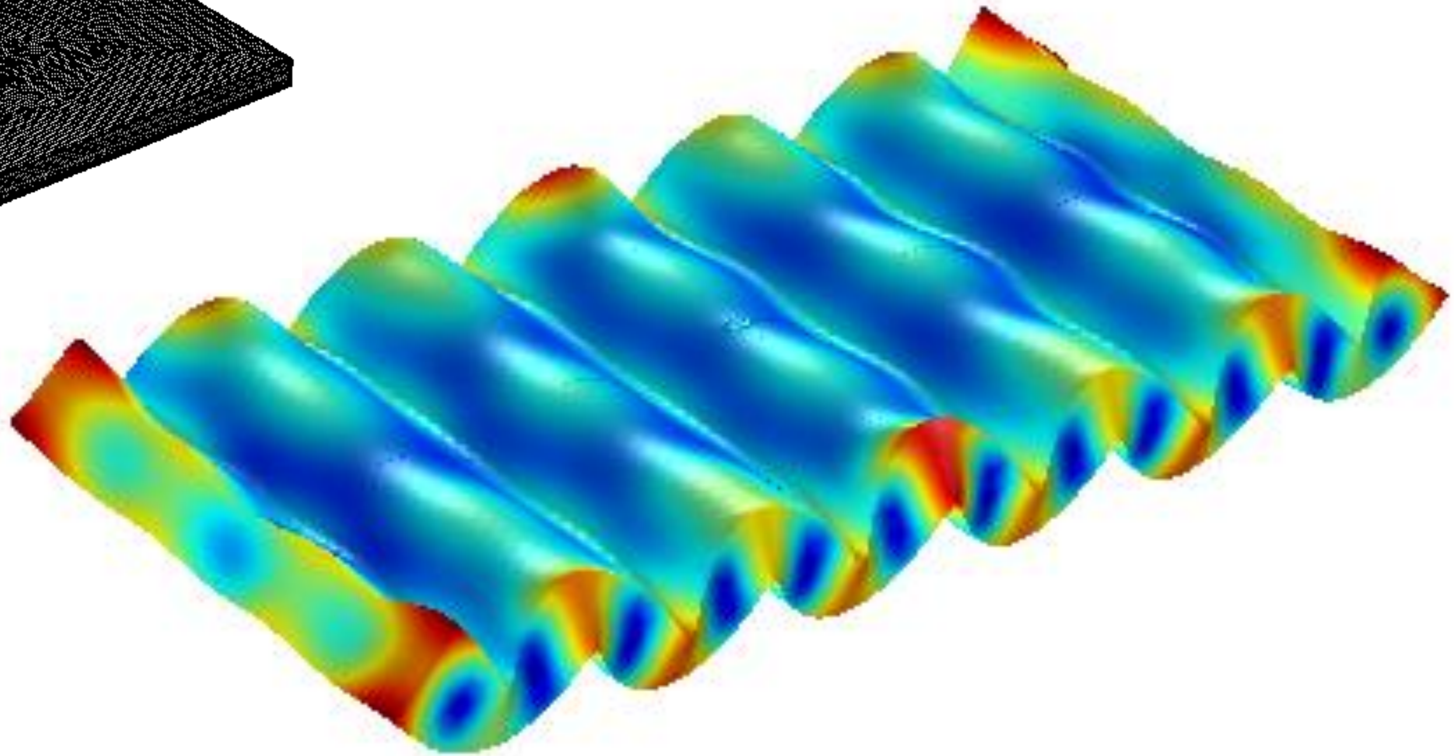
TRANSDUCER DESIGN
RECTANGULAR PLATE

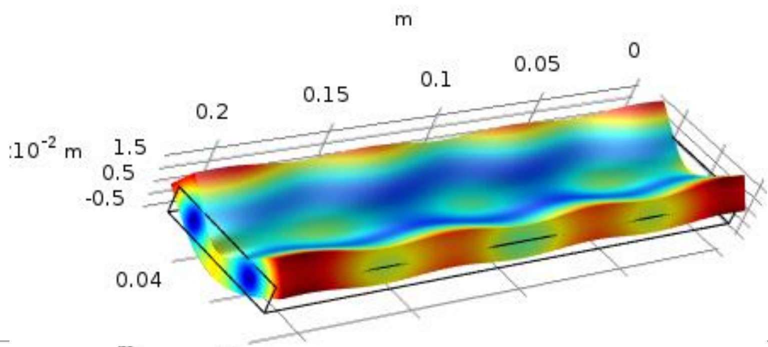


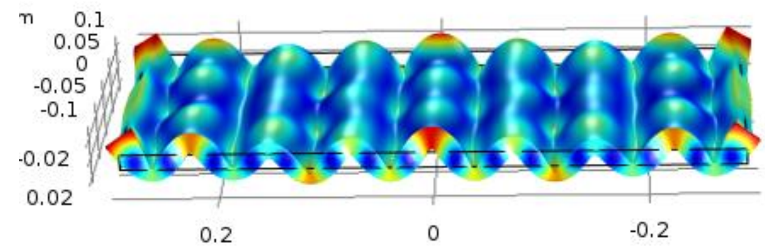


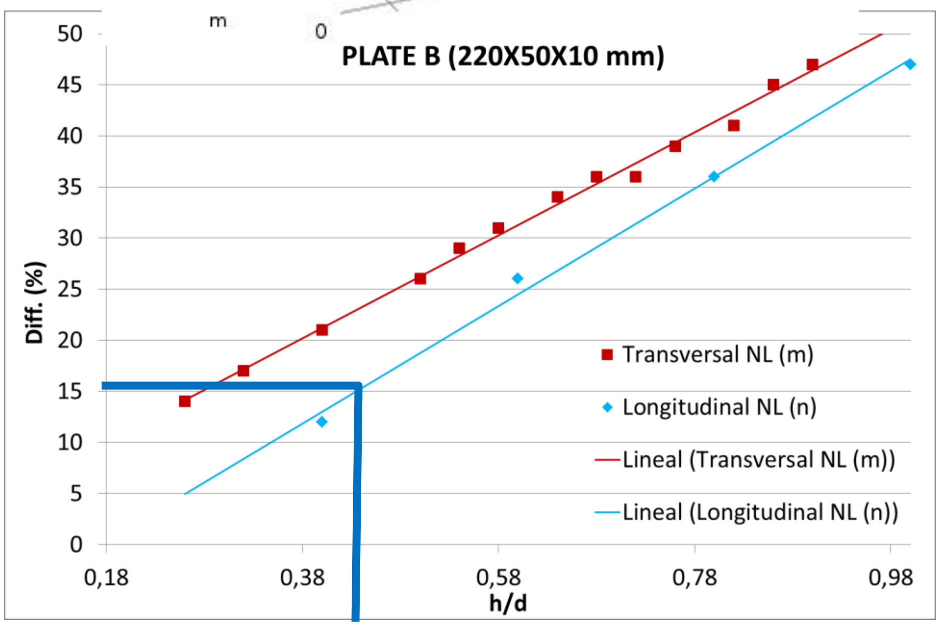


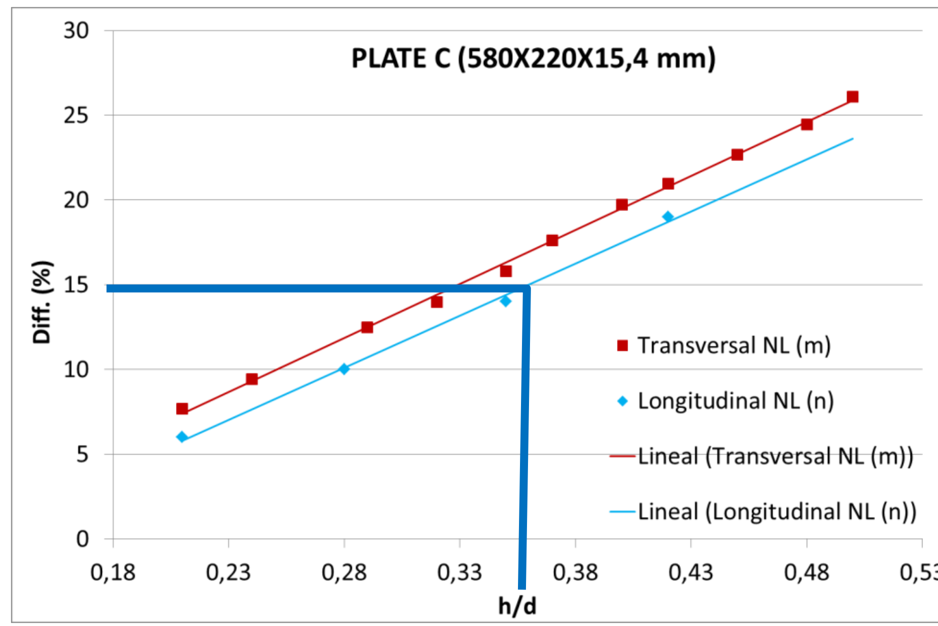
$$f_{m,n}^2 = \frac{h^2}{4.86\rho}\left[\frac{D_x}{L_x^4}\left(\frac{2m-1}{2}\right)^4 + \frac{D_y}{L_y^4}\left(\frac{2n-1}{2}\right)^4\right] + m^2n^2 f_{1,1} \quad (1)$$

VIBRATION OF RECTANGULAR PLATES









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