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

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HPU TRANSDUCER WITH RECTANGULAR RADIATOR
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TRANSDUCER DESIGN
LANGEVIN TYPE TRANSUDER
Considerations regarding the design of a power ultrasonic transducer with flat rectangular plate

**TRANSDUCER DESIGN**

**MECHANICAL AMPLIFIER**

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

![Graph showing total displacement vs. arc length](image)
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INDUSTRIAL APPLICATIONS

Ultrasonic defoaming

Mass transfer enhancement in food drying

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

Static solution
Dynamic solution
Total solution

System without prestress
System with prestress
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\[
 f_{m,n}^2 = \frac{h^2}{4.86\rho} \left[ \frac{D_x (2m - 1)}{L_x^4} + \frac{D_y (2n - 1)}{L_y^4} \right] + m^2n^2f_{1,1} \tag{1}
\]

**VIBRATION OF RECTANGULAR PLATES**

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

\[ + m^2n^2f_{1,1} \]

\( f_{m,n} \) 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.
\( \rho \) 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.

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

(1)

VIBRATION OF RECTANGULAR PLATES

<table>
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<tr>
<th>m</th>
<th>( f_r ) (Theoretical)</th>
<th>( f_r ) (Numerical)</th>
<th>Difference</th>
<th>Diff (%)</th>
<th>( d ) (distance between NL)</th>
<th>h/d</th>
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\[ f_{m,n}^2 = \frac{h^2}{4.86 \rho} \left[ \frac{D_x}{(2m - 1)^4} + \frac{D_y}{(2n - 1)^4} \right] + m^2 n^2 f_{1,1} \quad (1) \]
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\[
f_{m,n} = f_{\text{theoret}} \cdot \left(1 - 0.5 \frac{h}{d}\right)
\]

Plate A (570x308x34 mm)
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\[ f_{m,n}^2 = \frac{h^2}{4.86\rho} \left[ \frac{D_x}{(2m-1)^4} + \frac{D_y}{(2n-1)^4} \right] + m^2n^2f_{1,1} \]  

(1)
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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TRANSDUCER DESIGN
RECTANGULAR PLATE
Considerations regarding the design of a power ultrasonic transducer with flat rectangular plate

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

\[ (1) \]