Characterisation of Langevin transducers
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Overview
Langevin transducers, also commonly known as sandwich or stack transducers, at their most basic, are generally constructed from four fundamental components; front mass, back mass, piezoceramic stack and are held together under a compressive pre-load with a stud or bolt. It is traditionally proposed that the piezoceramic stack is positioned at or close to the vibrational nodal point of the longitudinal mode, however, this also corresponds with the position of highest dynamic stress. Ultrasonic devices are inherently nonlinear when driven at high excitation levels, and it is well documented in literature that piezoceramics, partly due to their low linear stress threshold, are a source of nonlinear behaviour. Therefore, this study investigates whether locating the piezoceramic stack away from a position of intrinsic high stress will reduce or alter the nonlinear behaviour of the device.

Transducers
Half wavelength transducers with brass endmasses and three different stack locations.

Resonant frequency and mode shape extraction
The transducers initially designed through finite element analysis (FEA) and were tuned to vibrate at the 1\textsuperscript{st} longitudinal mode at approximately 28kHz. The predicted resonant frequencies and mode shapes were validated through experimental modal analysis (EMA).

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Endmass length ratio</th>
<th>Resonant frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1:1</td>
<td>28568</td>
</tr>
<tr>
<td>II</td>
<td>1:4:3:4</td>
<td>28686</td>
</tr>
<tr>
<td>III</td>
<td>1:8:7:8</td>
<td>28770</td>
</tr>
</tbody>
</table>

Summary of low excitation properties of transducer configurations

Stress Analysis
Stress distribution throughout the transducers was investigated through FEA. Each transducer was simulated to oscillate under steady state conditions at a common vibrational amplitude.

Conclusions
The behaviour of Langevin transducers with differing piezoceramic stack positions has been investigated at low and high levels of vibrational amplitude. From this work a number of observations can be made:

- Good correlation was found to exist between resonant frequencies and mode shapes of the 1\textsuperscript{st} longitudinal mode shape and resonant frequency:
- Residual stress distribution throughout the transducers was investigated through FEA. Each transducer incorporating between successive bursts to allow heat dissipation.

Low excitation measurements
Admittance and phase angle measurements of transducer configurations at low excitation

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Resonant frequency (Hz)</th>
<th>Admittance (Q)</th>
<th>Phase angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>28568</td>
<td>393.4</td>
<td>225.1</td>
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<tr>
<td>II</td>
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<tr>
<td>III</td>
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References