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Can power ultrasonic devices be printed?

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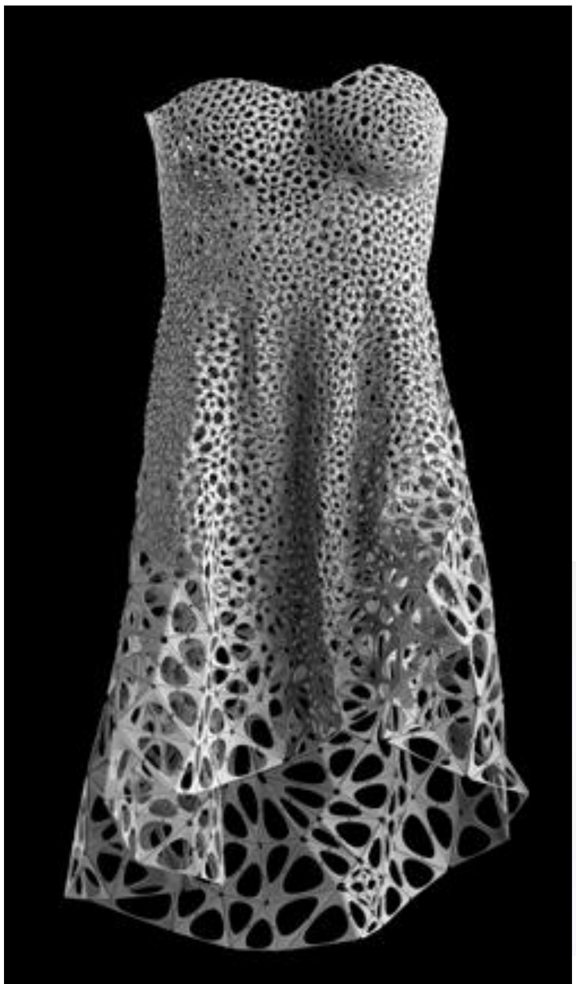
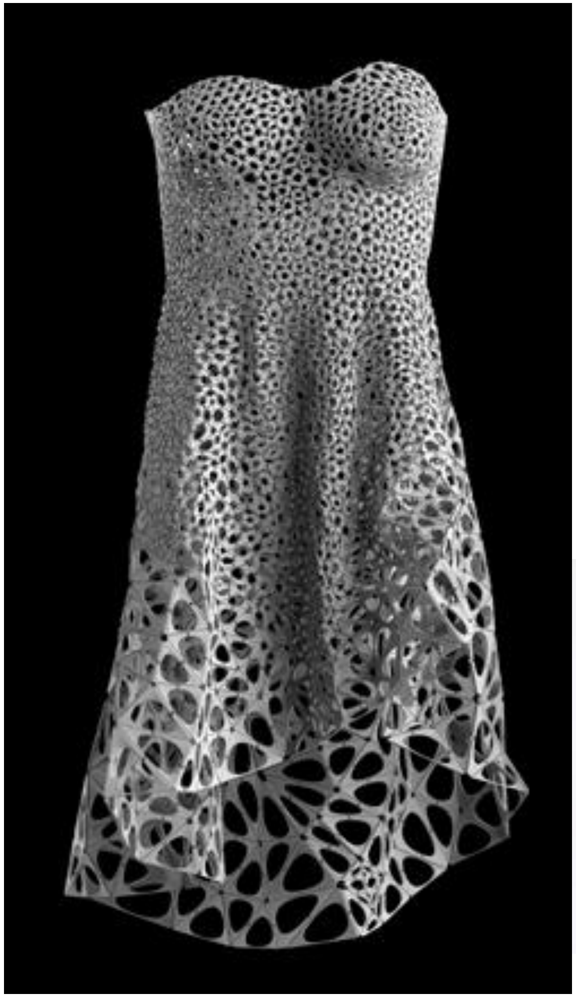
Additive manufacture - Polymers / Ceramics



Additive manufacture - Polymers / Ceramics

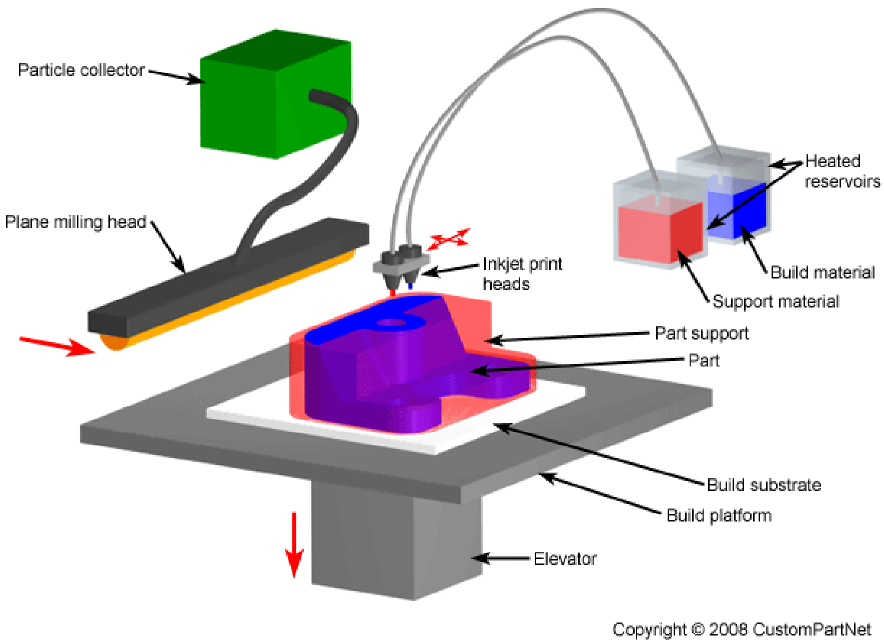


Additive manufacture – Alloys

Fundamentals: AM processes

Extrusion deposition

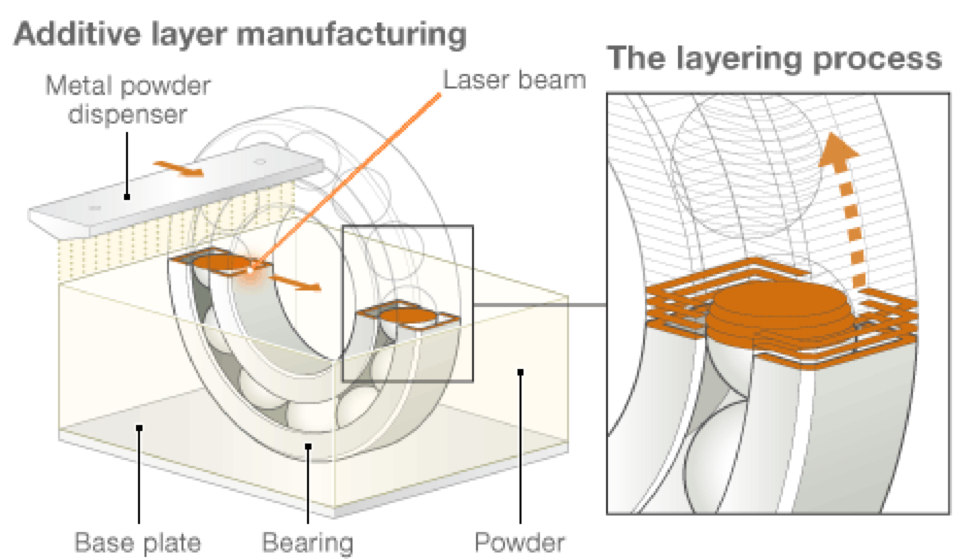
Material is deposited direct on to substrate or previous layer



http://www.custompartnet.com/wu/images/rapid-prototyping/inkjet-printing.png

Binding of granular materials

Energy source is directed or a binder is applied to powder bed



http://stephaniewooddesign.co.uk/amaze-project-aims-to-take-3d-printing-into-metal-age/

Direct Metal Laser Sintering (DMLS)

Advantages (my opinion)

- Minimal material wastage
- Potential for highly complex shapes
- Short lead time: CAD model to manufactured part
- Fully machinable

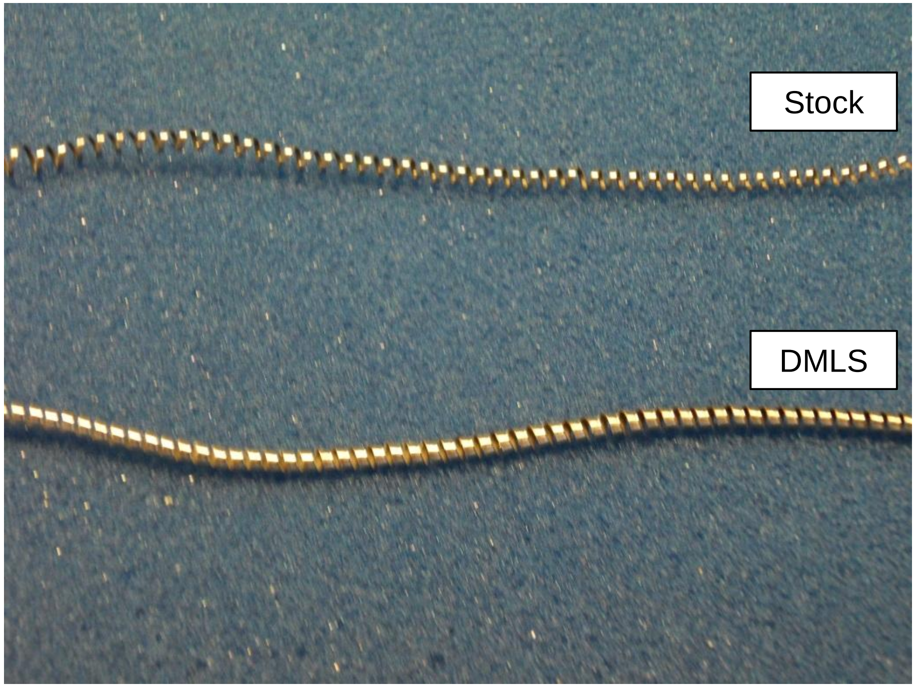
Disadvantages (my opinion)

- Expensive
- Part surface required finishing
- Holes and threaded features required machined
- Cylindrical part not fully cylindrical

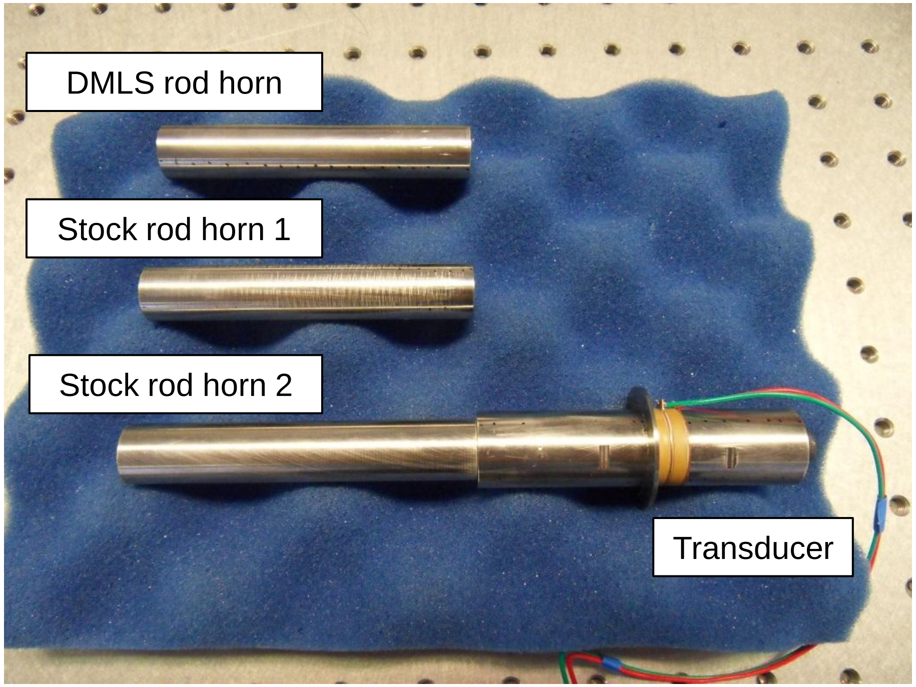
Optimisation of bracket

Resonant parts

- Two rod horns machined from Ti6Al4V stock material
- One rod horn ‘printed’ via DMLS from Ti6Al4V powder



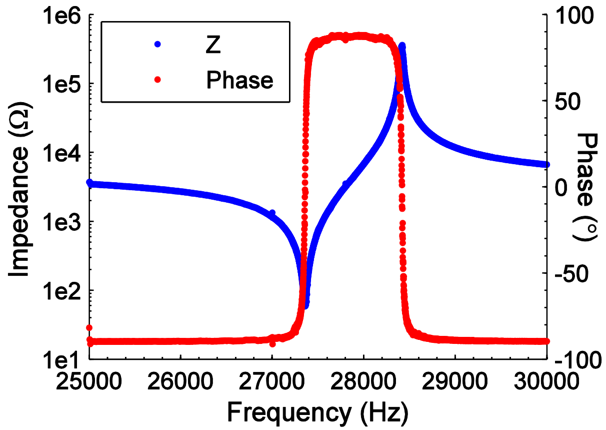
Titanium swarf



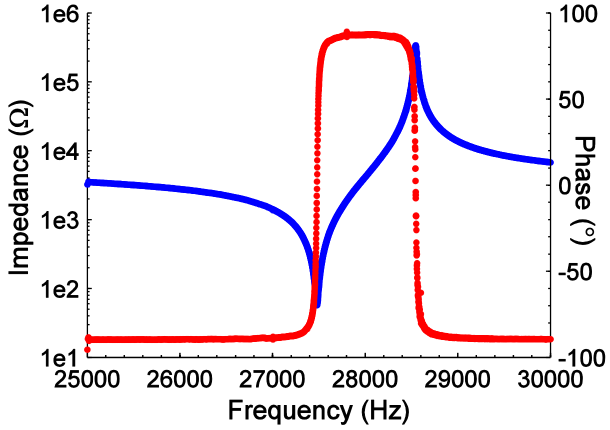
Resonant device

Impedance characteristics

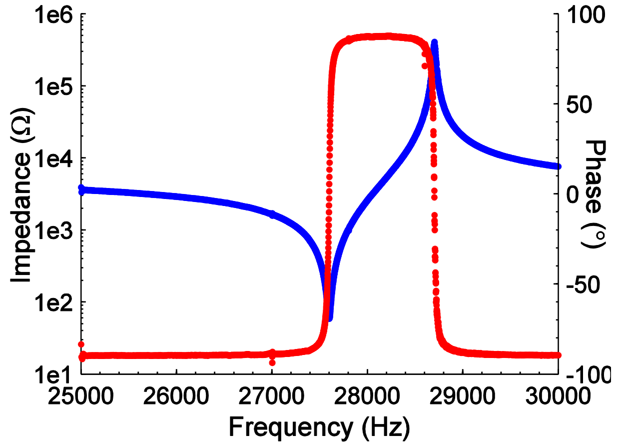
Impedance traces



DMLS rod horn



Stock rod horn 1



Stock rod horn 2

Impedance characteristics

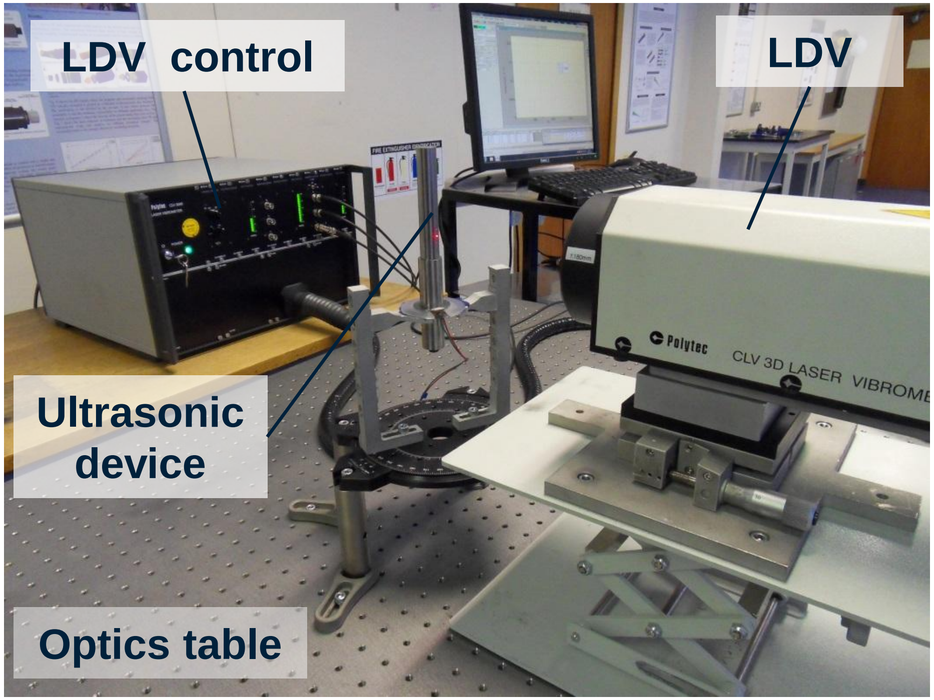
Impedance data

	DMLS rod horn	Stock rod horn 1	Stock rod horn 2
f_s	27359Hz	27480Hz	27600Hz
f_p	28416Hz	28544Hz	28705Hz
Z_{fs}	58Ω	57Ω	59Ω
k_{eff}	0.2702	0.2705	0.2748
Q_m	977	981	986

	Average stock value	DMLS variation from average stock value	% diff (DMLS v average stock)
f_s	27540Hz	-181Hz	0.66%
f_p	28625Hz	-209Hz	0.73%
Z_{fs}	58Ω	0Ω	0.00%
k_{eff}	0.2726	-0.0024	0.89%
Q_m	984	-6	0.66%

Resonant frequency identification

Experimental modal analysis (EMA)



- Excitation frequency range 0-80 kHz
- Low power random excitation
- FRF resolution 1.6 Hz
- Experimental data undergoes curve fitting using ME’Scope software to generate a mathematical model of the transducer.

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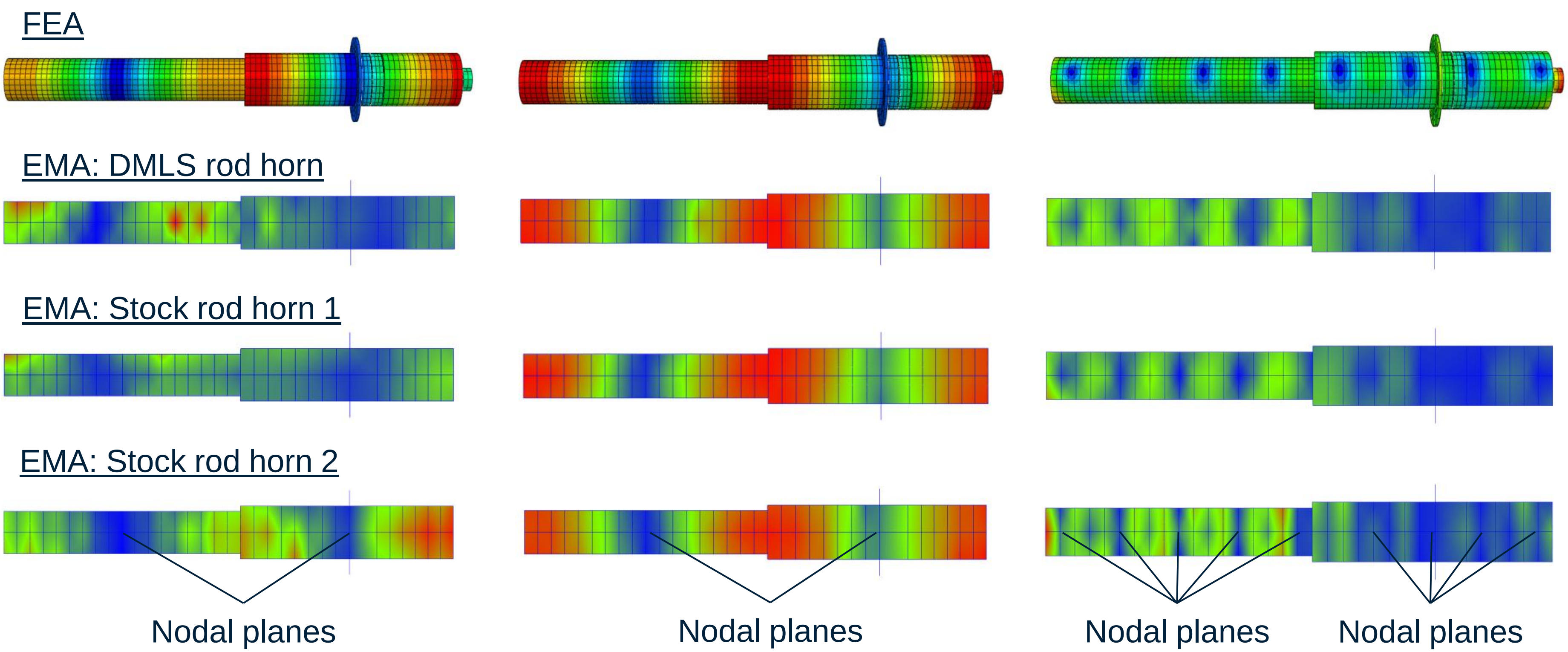
Resonant frequency identification

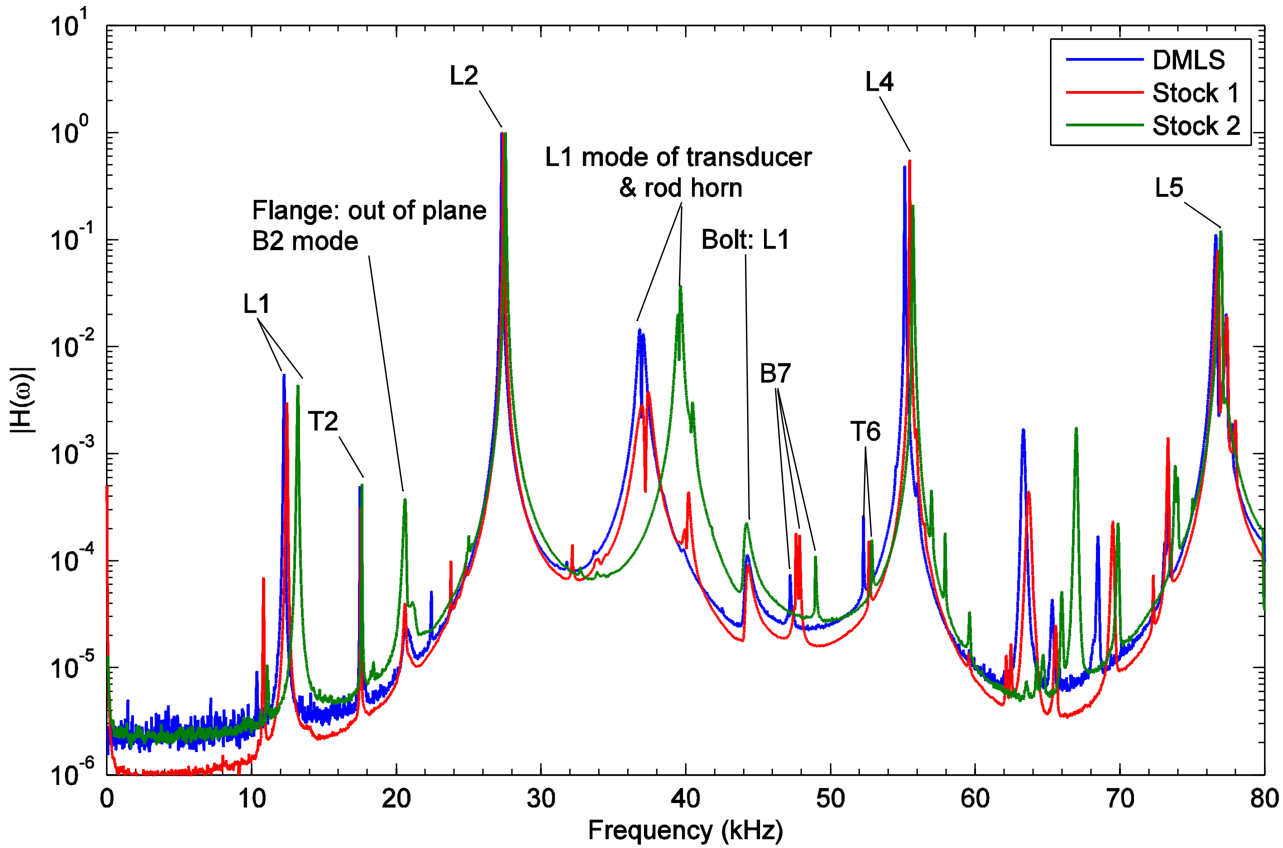
Modal analysis: Selected modes

2nd Torsional Mode | 2nd Longitudinal Mode | 7th Bending Mode



Resonant frequency identification

Modal Identification: FRFs with selected modes identified



Resonant frequency identification

Modal Identification: Selected modes of vibration

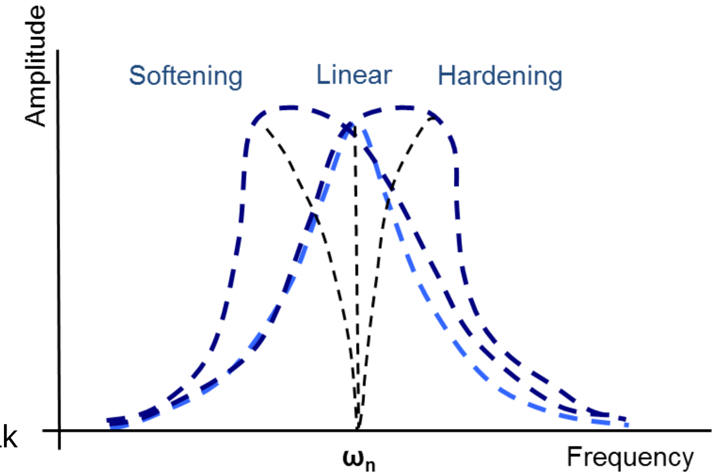
	2nd Torsional Mode f_r		2nd Longitudinal Mode f_r		7th Bending Mode f_r	
FEA	18394Hz		28369Hz		50056Hz	
EMA	f_r	% diff (FEA v EMA)	f_r (Hz)	% diff (FEA v EMA)	f_r	% diff (FEA v EMA)
DMLS Rod Horn	17492Hz	4.90%	27308Hz	3.74%	47231Hz	5.64%
Stock Rod Horn 1	17554Hz	4.56%	27416Hz	3.45%	47637Hz	4.83%
Stock Rod Horn 2	17638Hz	4.11%	27553Hz	2.88%	48986Hz	2.14%

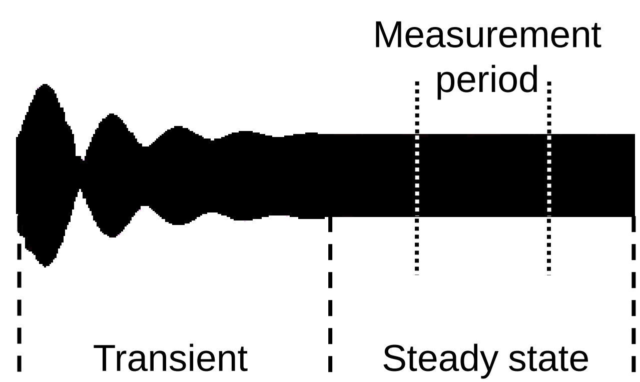
Harmonic characterisation

Bidirectional frequency sweep technique

Sine burst

- Burst length: 4000 cycles
- At 27.5 kHz: burst length 0.14 seconds
- Devices excited at; 1,10, 20, 30, 40 and 50 V_{peak}
- $1V_{peak}$ excitation a 2 second time delay between successive bursts
- 10 – 50 V_{peak} excitation level, a 10 second time delay between successive bursts





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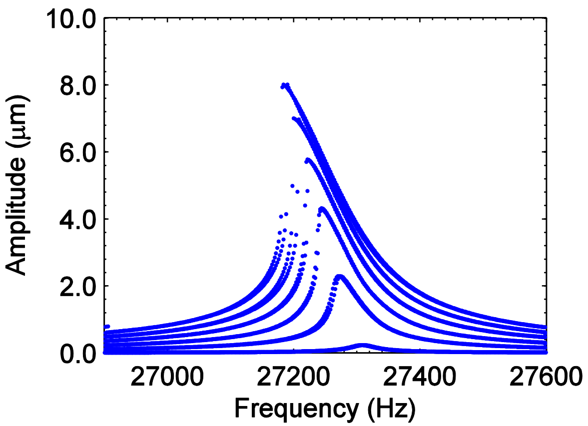
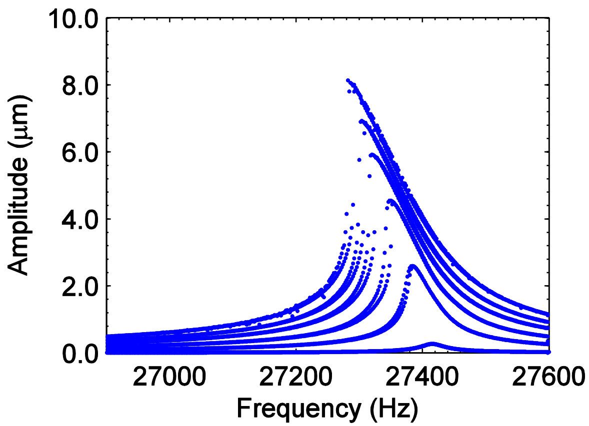
Harmonic characterisation

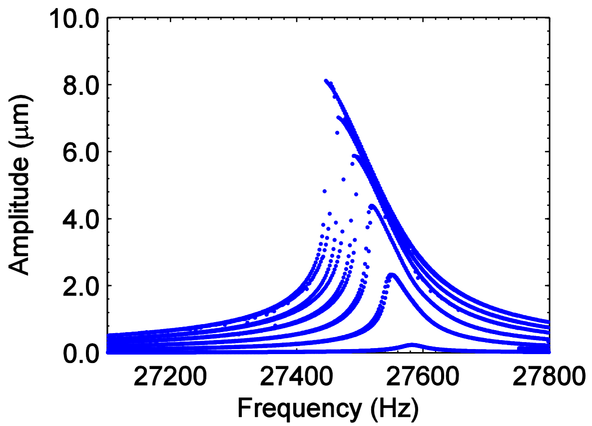
Bidirectional frequency sweep technique



DMLS rod horn

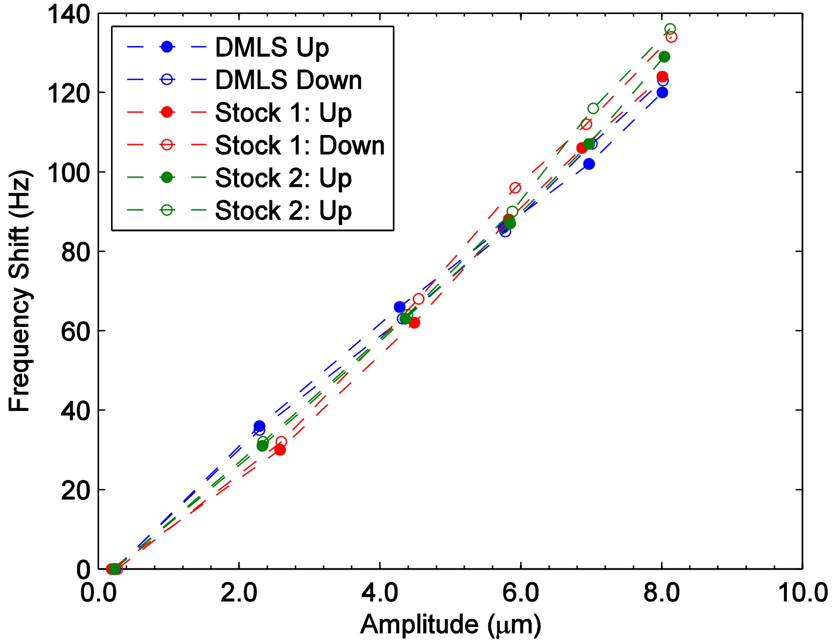


Stock rod horn 1

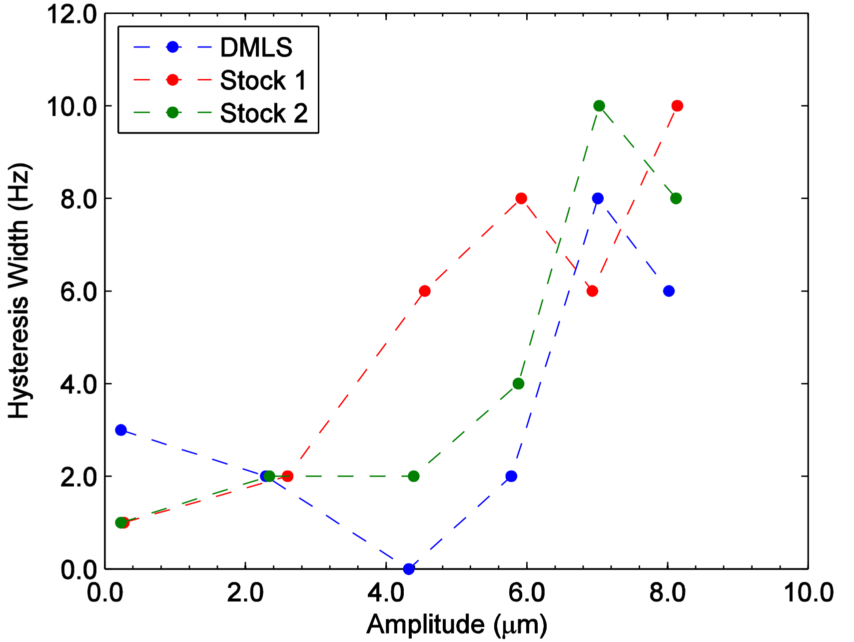


Stock rod horn 2

Harmonic characterisation



Frequency Shift



Hysteresis width

Findings

- Yes.
- Limited differences between DMLS part and those manufactured from stock were observed.
- Great potential for novel designs to be incorporated into power ultrasonic devices.
- Further work is required to understand of how the grain / microstructure of DMLS alloys influences vibrational behaviour.

Acknowledgements

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Thanks to CeramTec UK Ltd for supplying PZT rings for the transducer

Thanks for listening

Questions?