University of Glasgow | School of Engineering

40th Annual Symposium of the Ultrasonic Industry Association
Glasgow, 23rd May 2011

Characterisation of an ultrasonic transducer connected to quarter and full wavelength horns

Andrew Mathieson, Andrea Cardoni, Niccolò Cerisola

University of Glasgow | School of Engineering

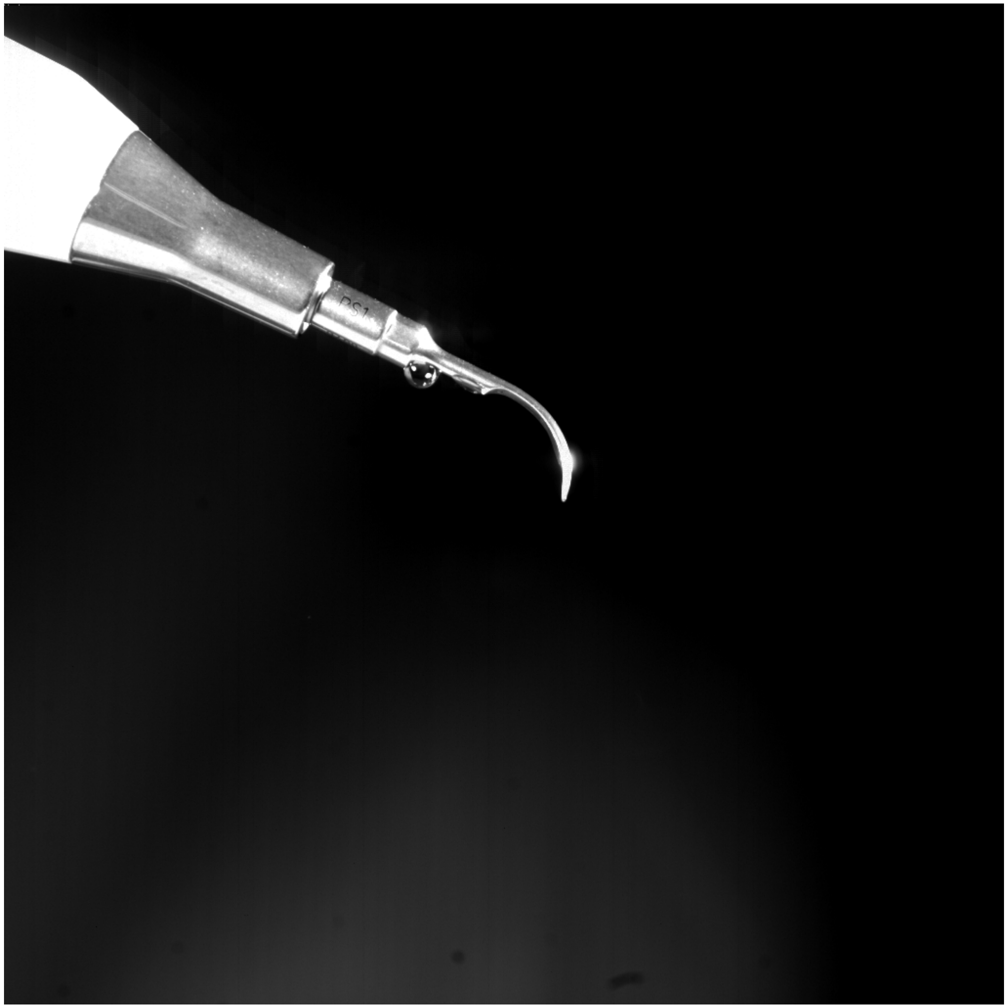
UIA 2011: Medical session

Presenter: Andrew Mathieson
Systems, Power & Energy research division
School of Engineering
University of Glasgow

Co-authors: Andrea Cardoni
Pusonics S.L
Arganda del Rey
Madrid, Spain

Niccolò Cerisola
Mectron Medical Technology
Carasco, GE, Italy

Ultrasonic scaling device



Photron fastcam ultima APX

Recording

Frame rate: 500fps

Resolution: 1024x1024

Nº of frames: 963

Video

Frame rate: 30fps

Mectron dental transducer with PS1 scaling insert

Ultrasonic cutting device

Mectron dental transducer with OT7 cutting insert

Photron fastcam ultima APX

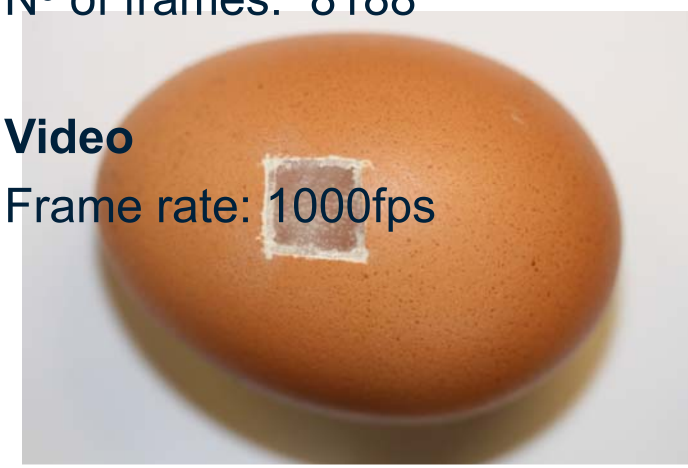
Window cut in egg

Recording

Frame rate: 4000fps

Resolution: 512x512

Nº of frames: 8188



Video

Frame rate: 1000fps

Aim of Research

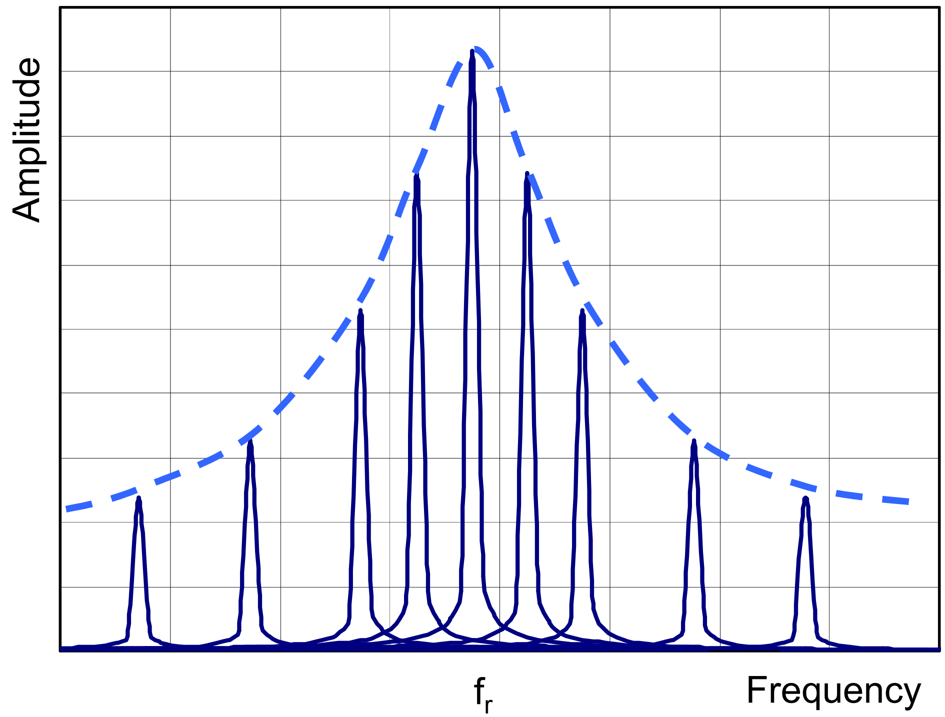
To create design criteria for stable power ultrasonic systems through understanding sources and causes of nonlinear behaviour

Linear response of ultrasonic devices

Excitation at individual frequencies

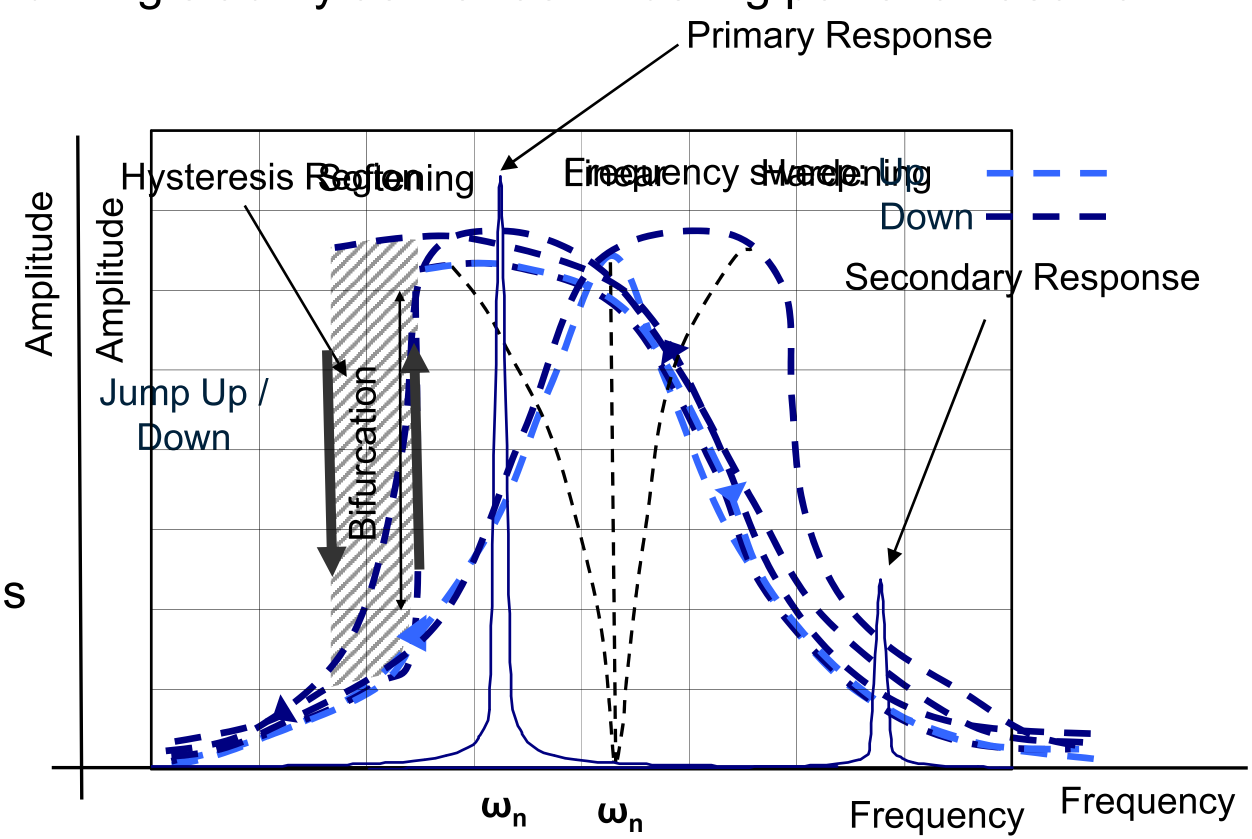
Continuous / burst swept sine wave

Low excitation levels



Nonlinear responses of ultrasonic devices

Can significantly influence driving stability as well as hindering power ultrasonic system development



Nonlinear behaviour

Frequency Shifts

Softening / Hardening effect

Bifurcations

Jump-resonance hysteresis

Multi-modal responses

Source of nonlinear behaviour

Nonlinear behaviour is directly influenced by:

Application of high stresses

- High vibration amplitudes

Dielectric, mechanical and piezoelectric losses within piezoceramics

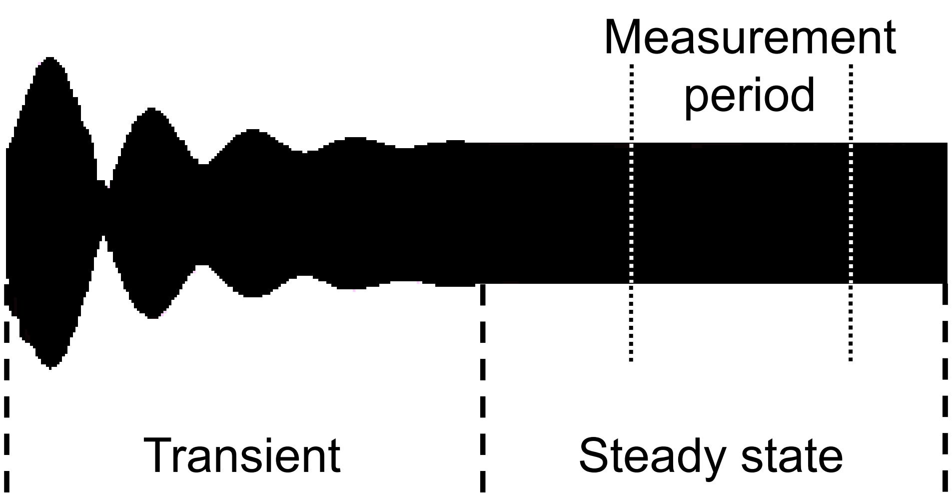
- Temperature increases
- High electric field

To understand nonlinear characteristics of the full ultrasonic device

- Remove thermal contributions from piezoceramics

Removal of thermal effect

<u>Burst sine sweep technique</u>



<u>Burst</u>

- 6000 cycles
- At 28kHz; 0.286 sec
- Time delay; 1-10 sec

Transducer & rodhorns

Mectron Transducer

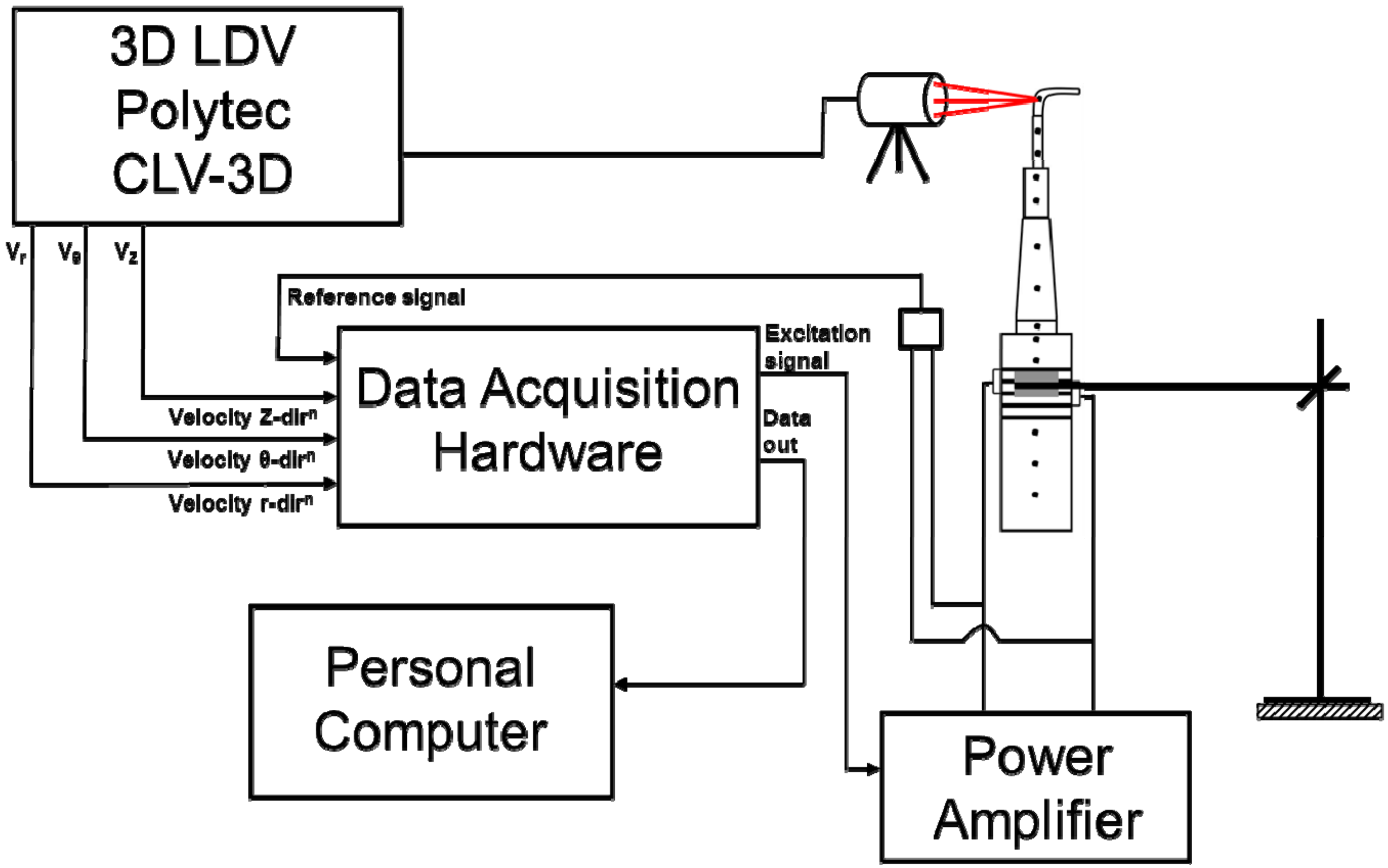
Aluminium 6082

Brass

Stainless Steel 316

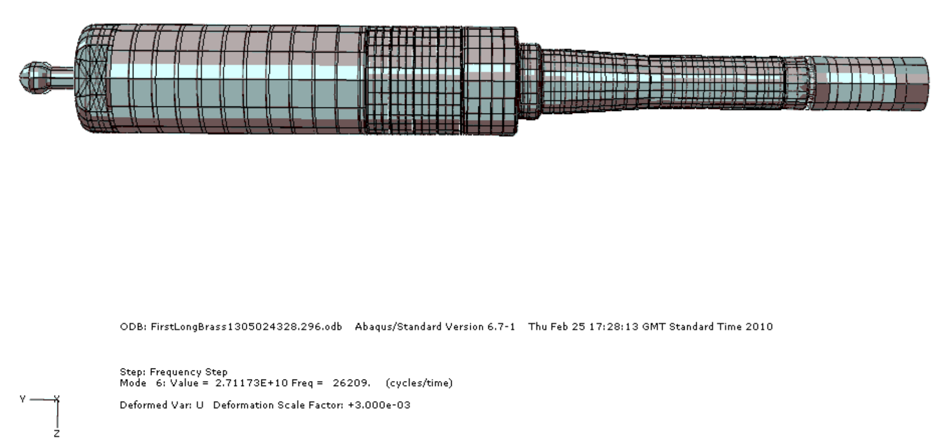
	Length of rod (mm)	
	¼ λ	Full λ
Aluminium	16	95
Brass	13	60
SS	13	110

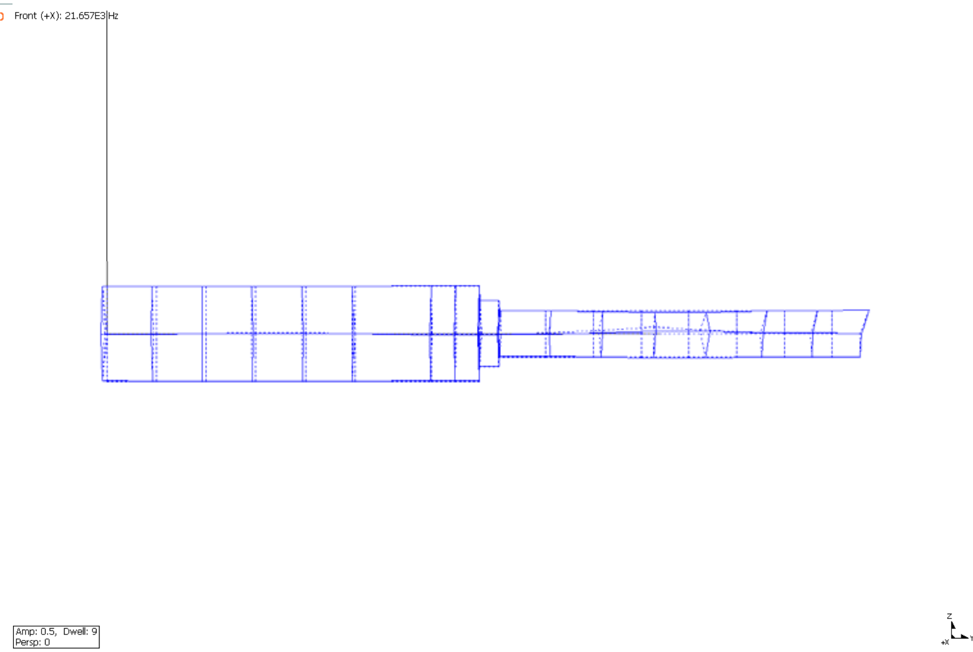
Experimental Modal Analysis



Design of rod horns: tuned mode

Quarter wavelength brass rod horn:



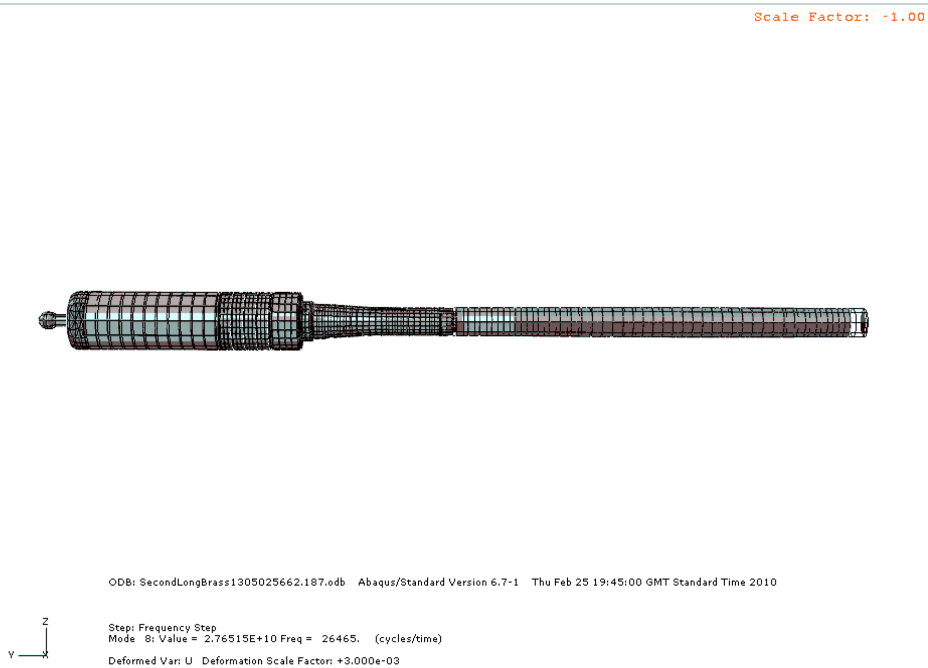


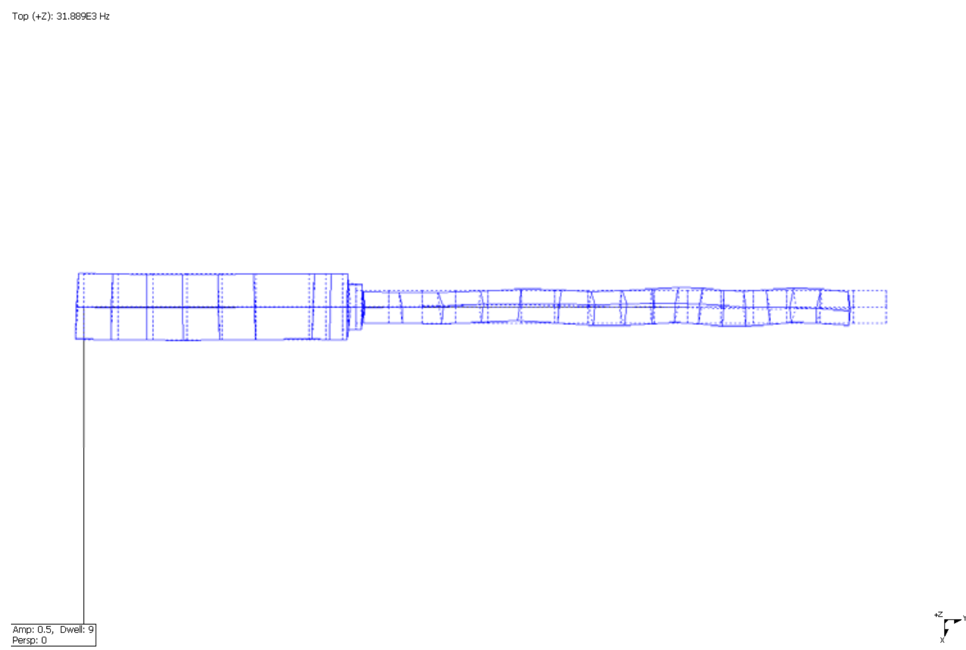
FEA: 22693Hz

EMA: 22345Hz

Design of rod horns: tuned mode

Full wavelength brass rod horn:





FEA: 31906Hz

EMA: 31889Hz

University of Glasgow | School of Engineering

UIA 2011: Medical session

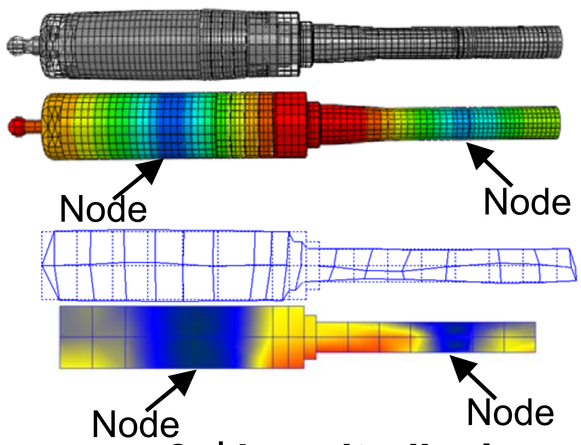
Design of rod horns: other longitudinal modes

FEA

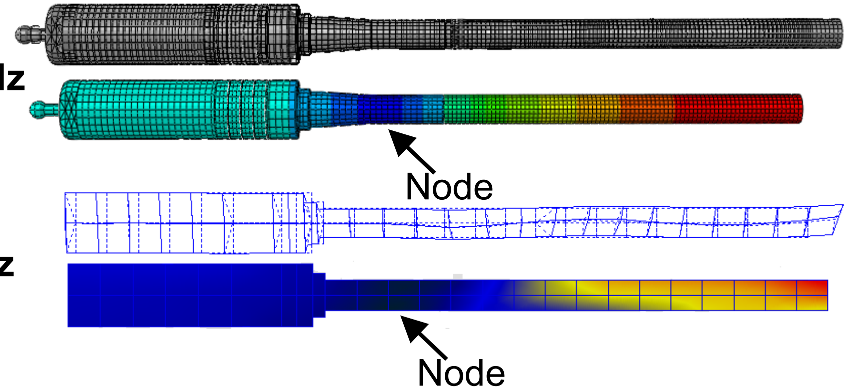
47604Hz **10186Hz**

EMA

43860Hz **9898Hz**



2nd Longitudinal mode



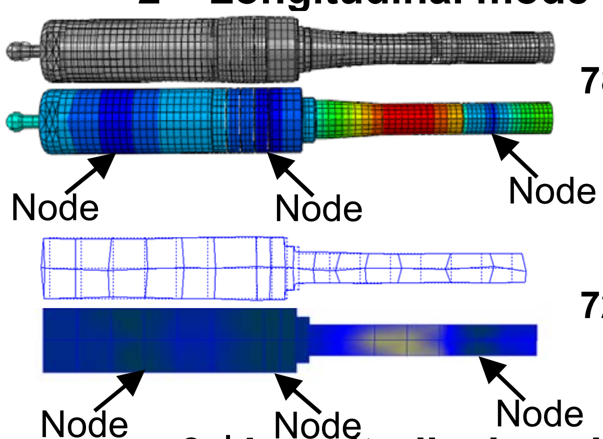
1st Longitudinal mode

FEA

78344Hz **46127Hz**

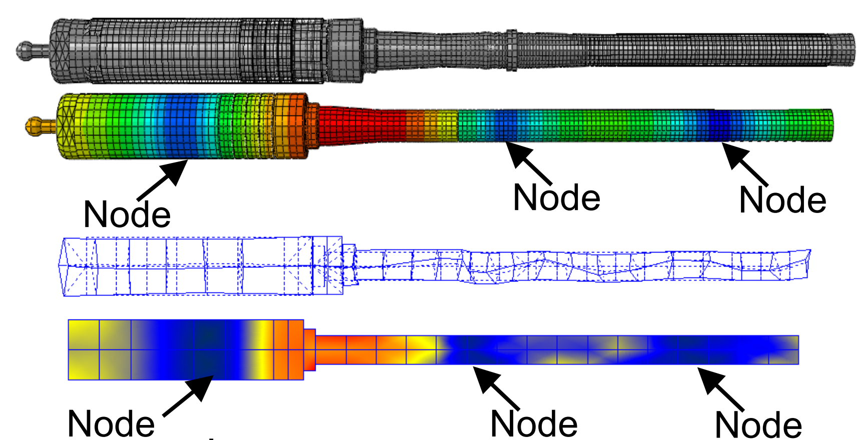
EMA

72530Hz **42975Hz**



3rd Longitudinal mode

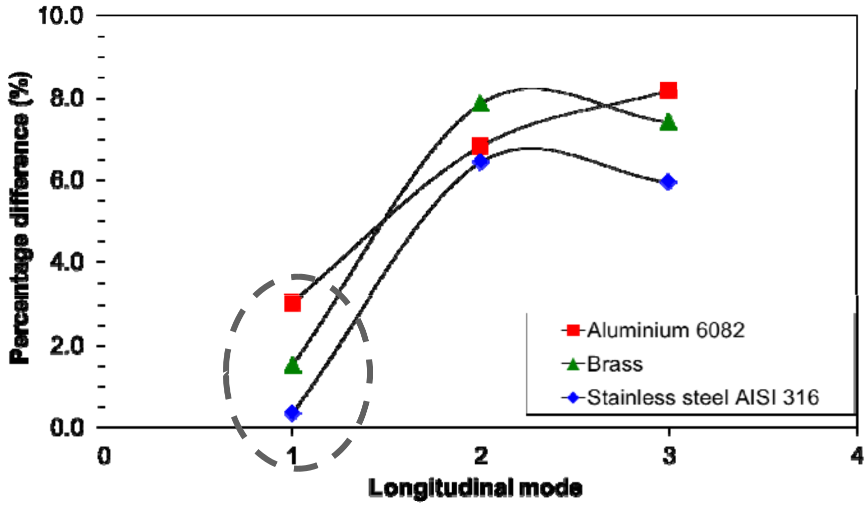
¼ wavelength brass rod horn



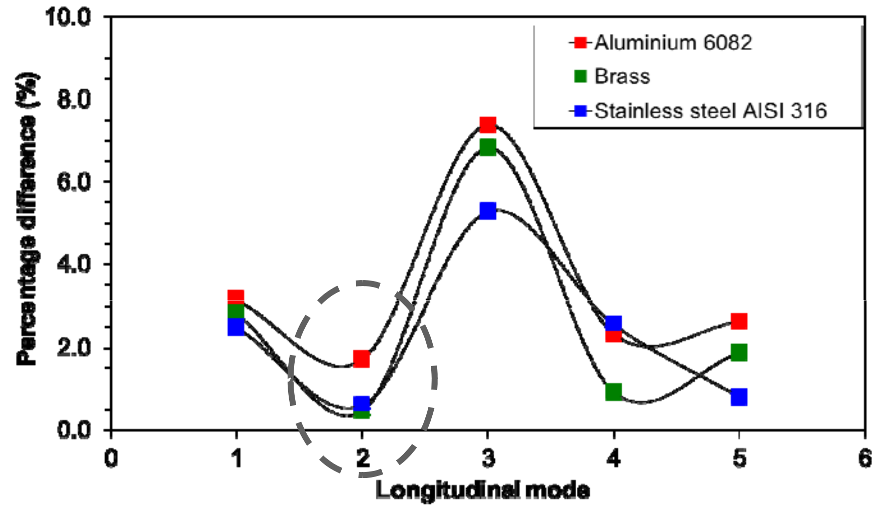
3rd Longitudinal mode

Full wavelength brass rod horn

Percentage difference between FEA & EMA



Tuned mode: 1st longitudinal



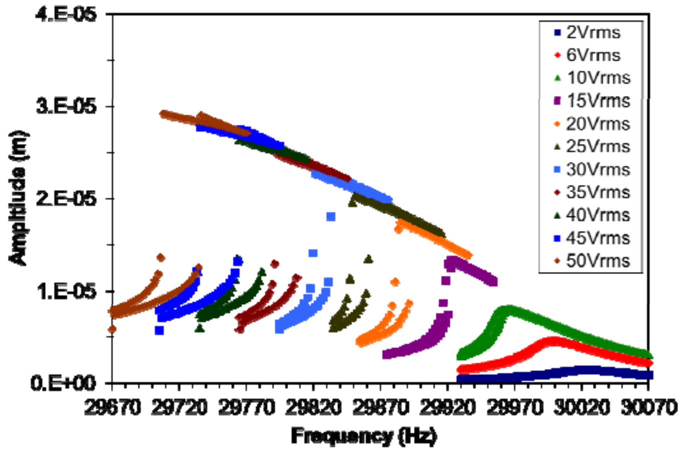
Tuned mode: 2nd longitudinal

¼ wavelength rod horn

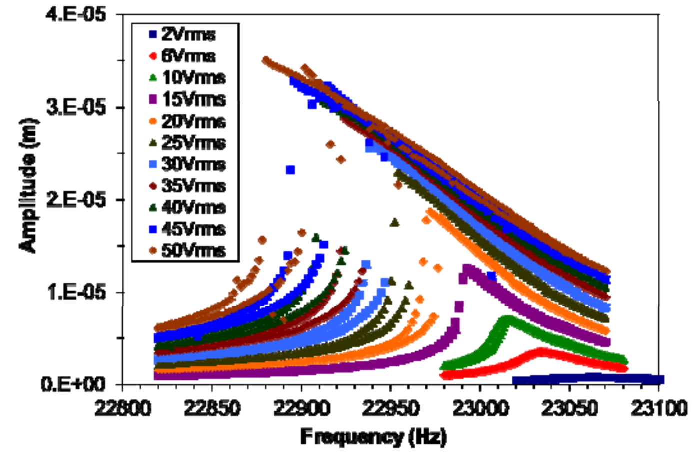
Full wavelength rod horn

Nonlinear characterisation

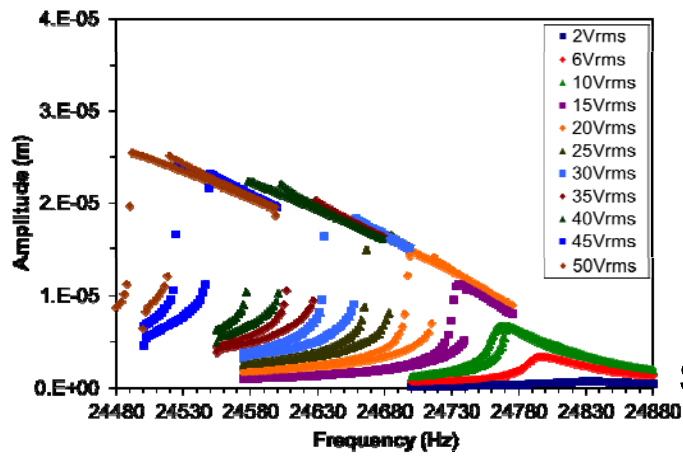
Frequency response plots: ¼ wavelength rod horns



Aluminium rod horn



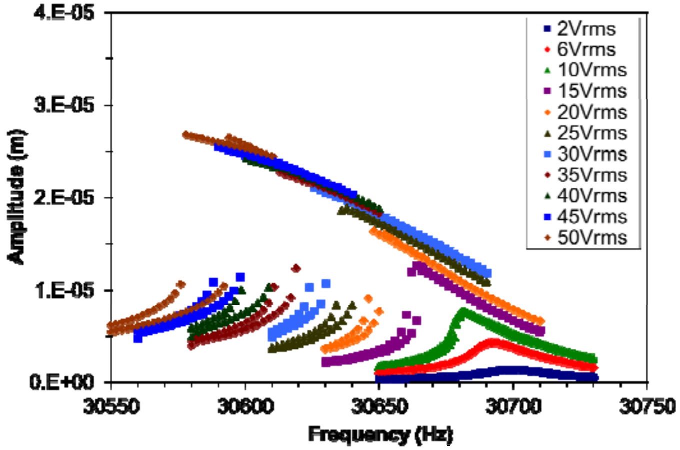
Brass rod horn



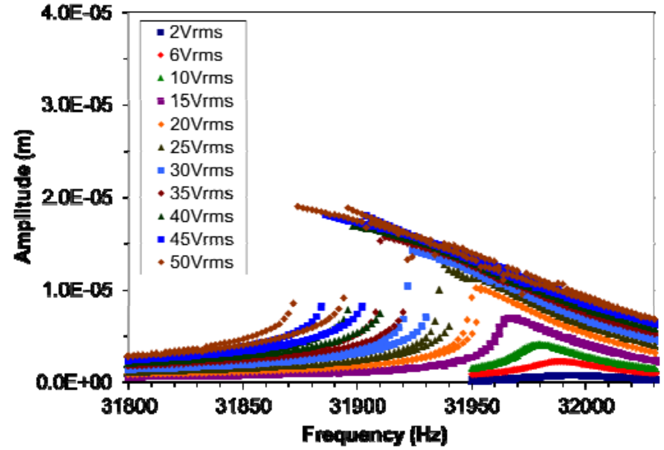
Stainless steel rod horn

Nonlinear characterisation

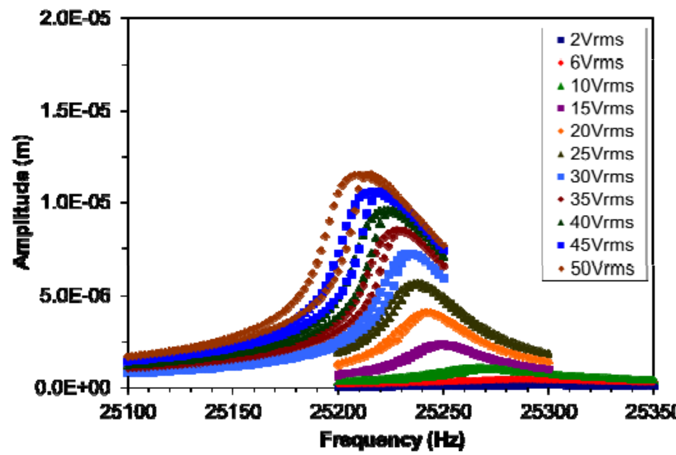
Frequency response plots: Full wavelength rod horn



Aluminium rod horn



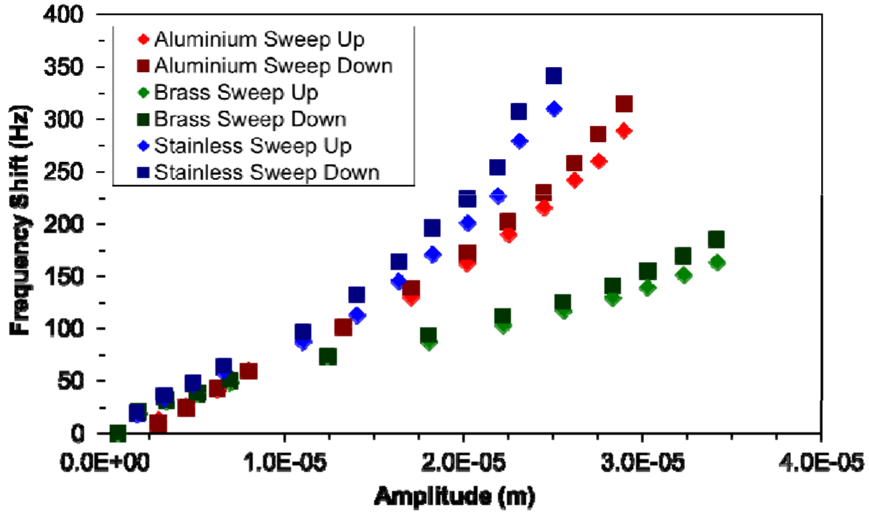
Brass rod horn



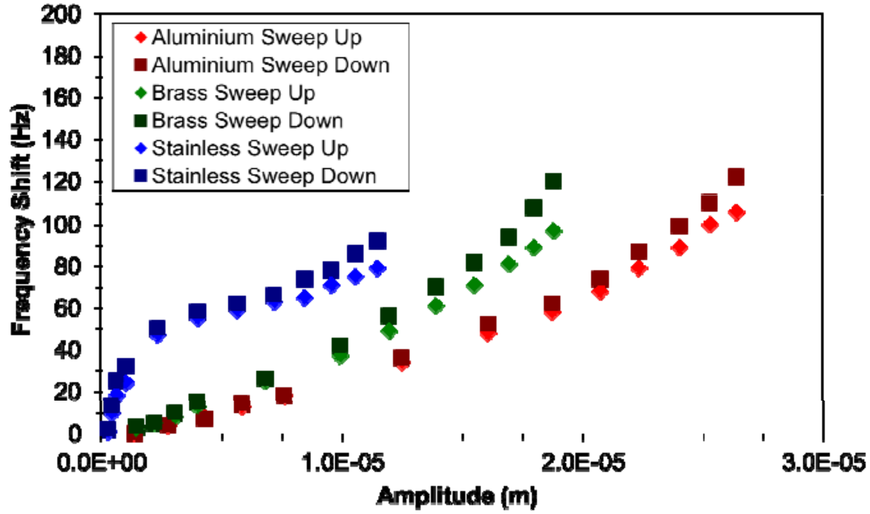
Stainless steel rod horn

Nonlinear characterisation

Frequency shift against vibration amplitude



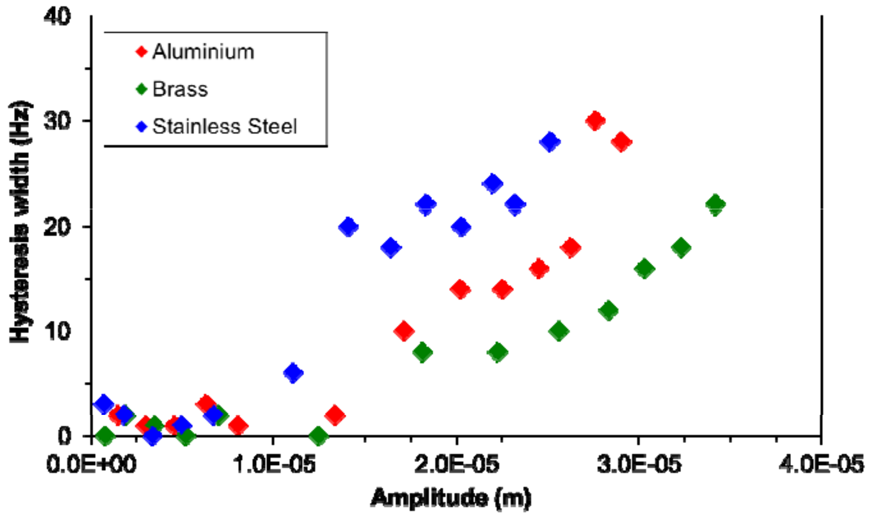
¼ wavelength rod horns



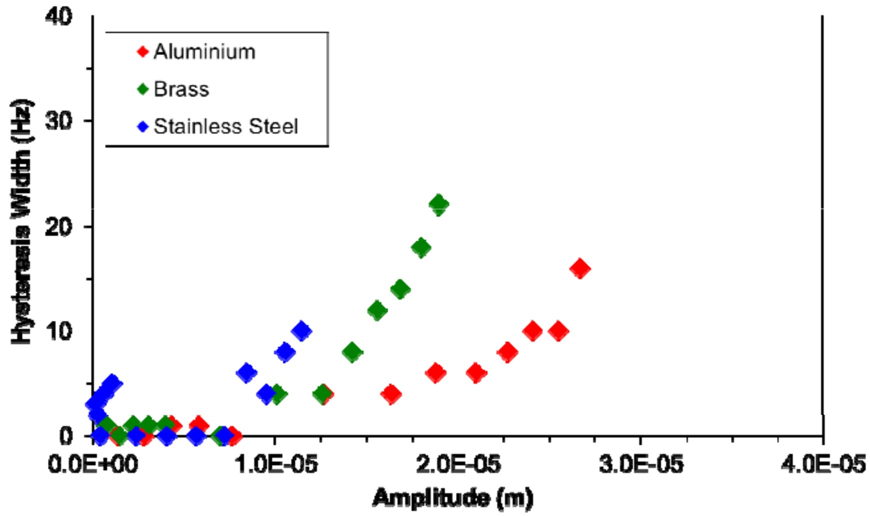
Full wavelength rod horns

Nonlinear characterisation

Hysteretic region width against vibration amplitude



¼ wavelength rod horns

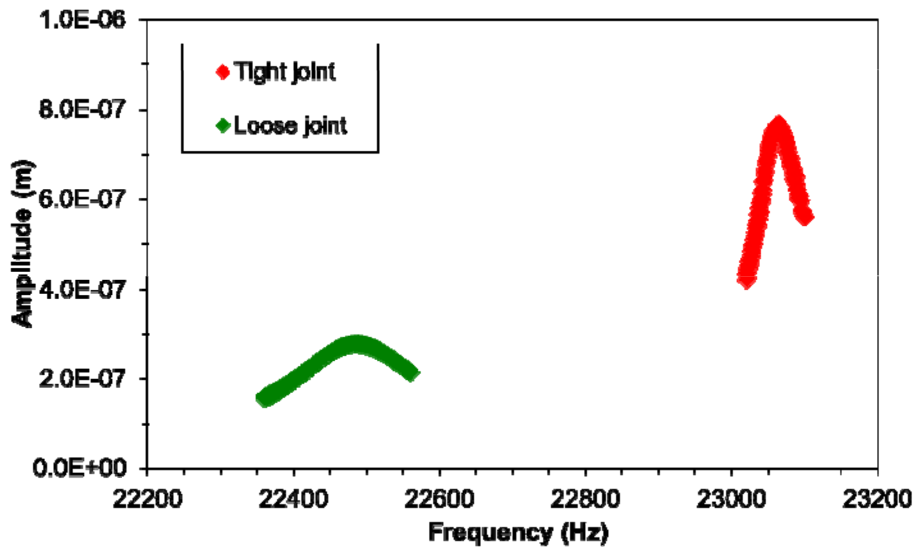


Full wavelength rod horns

Threaded joints

Joint tightness

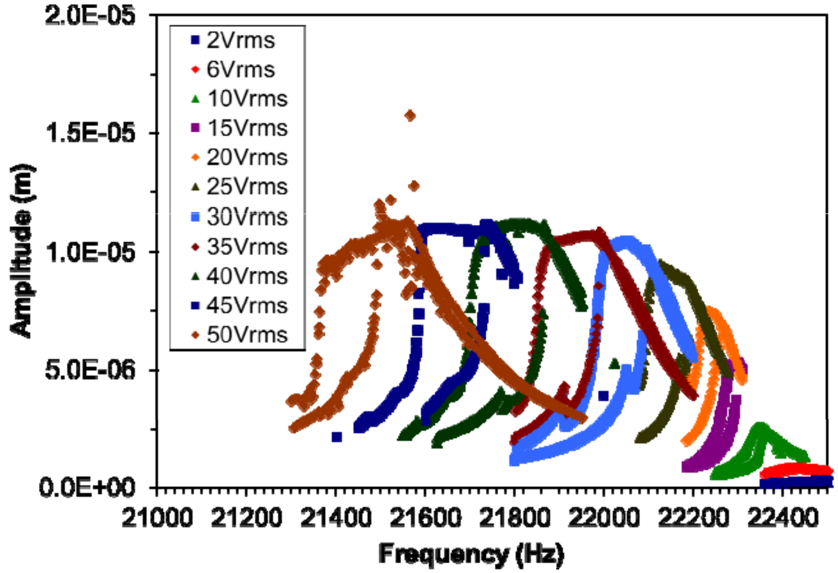
- Resonant frequency
- Damping
- Enhanced acoustic transmission
- Reliability
- Ultimately dependent on tensile strength of material



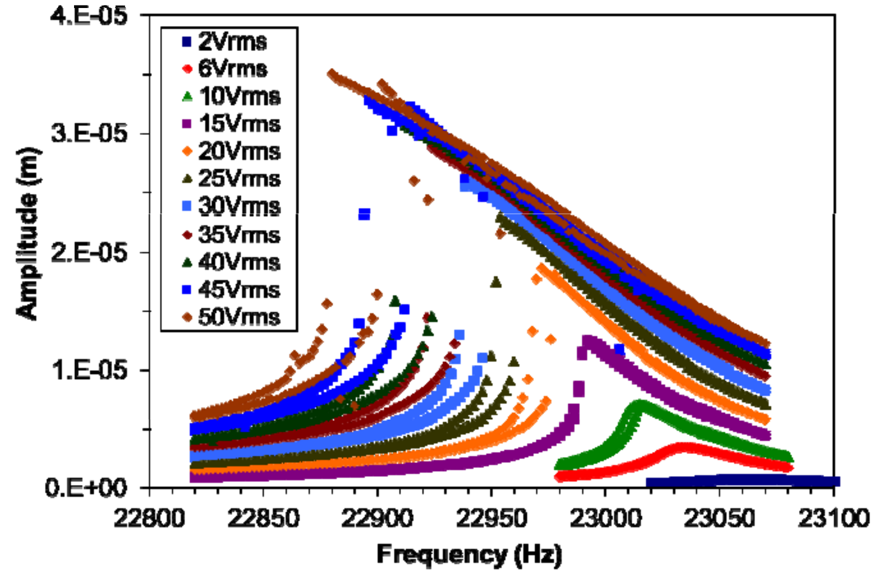
¼ λ rod horn assembly with different joint tightness

Nonlinear characterisation: Joint tightness

Frequency response



Low Q_m rod horn assembly
(looser joint)

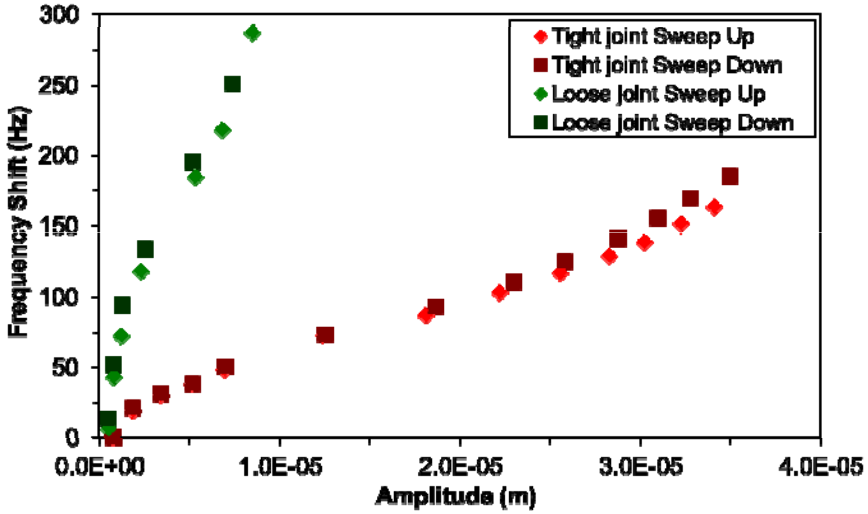


High Q_m rod horn assembly
(tighter joint)

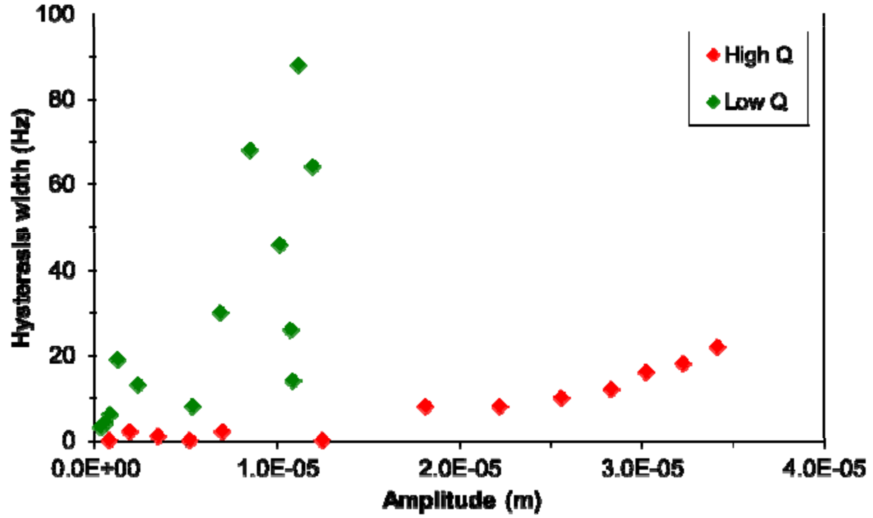
University of Glasgow | School of Engineering

UIA 2011: Medical session

Nonlinear characterisation: Joint tightness



Frequency shift against vibrational amplitude



Hysteretic region width against vibrational amplitude

Summary

- Correlation between FEA and EMA methods
  - Dependant on mode of vibration
- Characterisation of ¼ & full wavelength rod horns
  - Length of rod horn / mode of vibration
  - Material choice
- Joint tightness
  - Significant influence on nonlinear behaviours

Acknowledgements

Funding
Engineering and Physical Science Research Council (EPSRC)
Grant Nº: EP/E025811/1

Lab assistance: High power characterisation
Power Ultrasonic Group, Instituto de Acustica (CSIC), Madrid, Spain

Equipment
Mectron Medical Technology, Carasco, GE, Italy
EPSRC lone pool: High speed camera

Thank you for listening

Questions?

And the weather forecast will generally be:

<u>Sunny patches with heavy showers</u>

Literature

N.Aurelle, D. Guyomar, C. Richard, P. Gonnard, L. Eyraud, "Nonlinear behaviour of an ultrasonic transducer," Ultrasonics, vol. 34, 1996, pp.187-191.

J.J.Thomsen. "Vibrations and stability: Order and chaos" McCraw-Hill, 1997

A. Iula, F. Vazquez, M. Pappalardo & J.A. Gallego. "Finite element three-dimensional analysis of the vibrational behaviour of the Langevin-type transducer" Ultrasonics, 2002, 40, 513 – 517.

H Kumehara, K. Morimura, K. Maruyama, I. Yoshimoto "Characteristics of threaded joints in ultrasonic vibrating systems" Bulletin of JSME, Vol. 27, No. 223, 1984, pp117-123.

M. Umeda, K. Nakamura, S. Ueha, "Effects of Vibration Stress and temperature on the characteristics of piezoelectric ceramics under high vibration amplitude levels measured by electrical transient method" Japn. J. Appl. Phys, vol. 38, 1999 pp.5581-5585.

M. Umeda, K. Nakamura, S. Takahashi, & S. Ueha "An Analysis of Jumping and Dropping Phenomena of Piezoelectric Transducers using the Electrical Equivalent Circuit Constants at High Vibration Amplitude Levels" Japn. J. Appl. Phys, 2000, 39, 5623-5628.