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Material property evaluation of female breast tissue by Finite Element eigenvalue analysis

Michaela Hassmann (1), Jacqueline Dastl (2), Wolfgang Krach (2)
1. University of Vienna, Austria; 2. CAE Simulation & Solutions GmbH, Austria

Introduction

- Discomfort of breast motion : vertical amplitude [1], frequency [2]
- FE simulation: geometry [4,5], material parameters [3]

Aim of study

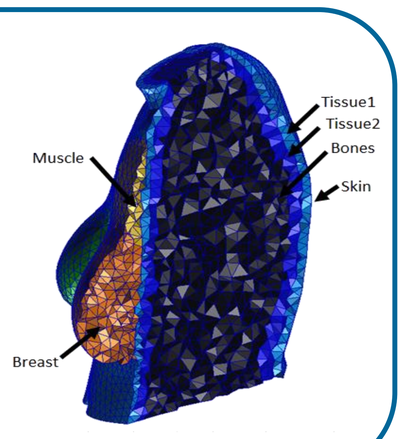
- Experimental free decay vs. FE eigenvalue analysis
- Evaluation of Young's modulus of each breast separately (N = 108)

54 women

- 33.7 ± 11.4 years
- bra size 75B to 95G

FE model

- 3D scan: upright standing on turntable
- Pre-processing: blender [4,5], Patran 2014.1
- Breast tissue: μ = 0.495, ρ = 1E-9 t/mm³
- Young's modulus: starting value E = 1 kPa [3]
- Solver: MSC Nastran 2014.1
- Eigenvalue analysis (SOL103)



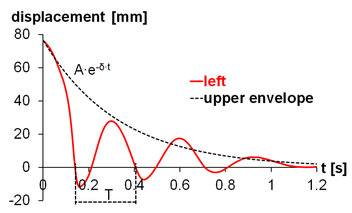
Experimental free decay

- Participants lifted their breasts with their hands as high as comfortable
- Highspeed camera (500 fps)
- Trajectories of left and right nipple
- Eigenfrequencies calculated using upper extrema [2,7]

Material property adaptation

- Eigenfrequency $f = 1/2\pi \cdot \sqrt{k/m}$ [Hz]
- Stiffness k [N/m]: proportional to Young's modulus E [kPa]
- E was fitted to experimental f (max. deviation 5 %): $E_{i+1} = \frac{f^2}{f_i^2} \cdot E_i$

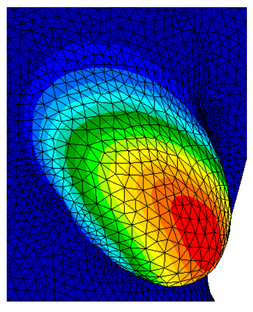
Eigenfrequency and damping

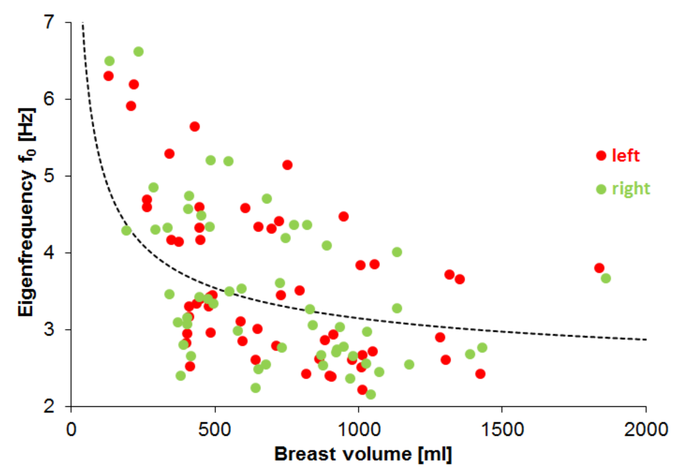


- Eigenfrequency $f = \frac{1}{T}$ [Hz]
- Damping $\zeta = \frac{\vartheta}{\sqrt{(2\pi)^2+\vartheta^2}}$ [-]

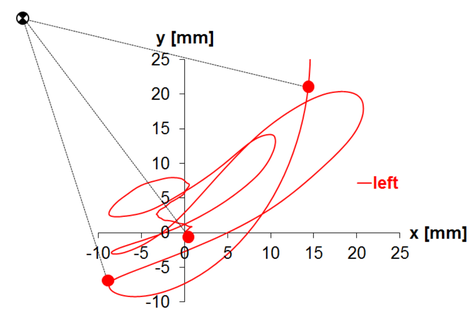
Results and discussion

- First eigenmode: similar to experiment
- E = 0.201 kPa (80B) to 2.481 kPa (95G)
- approximated as simple mass oscillator





- Thread pendulum rotated by approx. 50° of the vertical axis [2]



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