# Characterization of porous media absorption properties: nonlinear effects and Biot resonance


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➪ Even at relatively low acoustic levels, **amplitude-dependent effects are observed** on the measured absorption coefficient of various porous media

➪ The observed nonlinear effects are located in frequency around the **Biot resonance** of the sample

➪ The extracted Biot parameters of the porous media thus strongly depend on the excitation amplitude

## Typical observations of amplitude dependent effects

**Fig. 1:** *Picture of the glass wool sample and the melamine foam that exhibit nonlinear effects.*

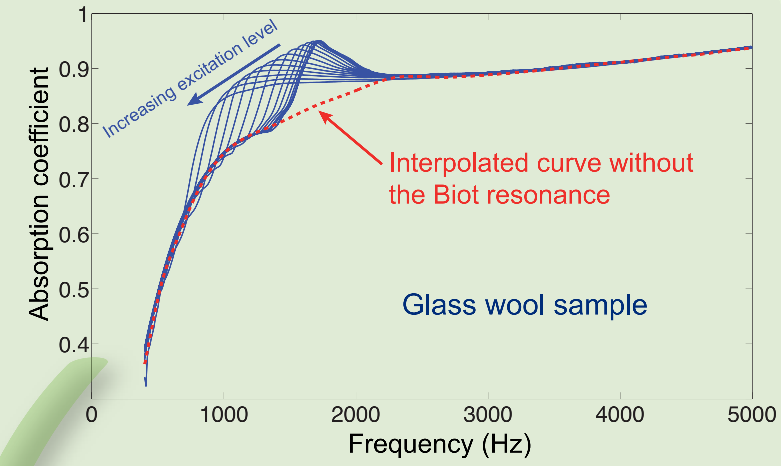
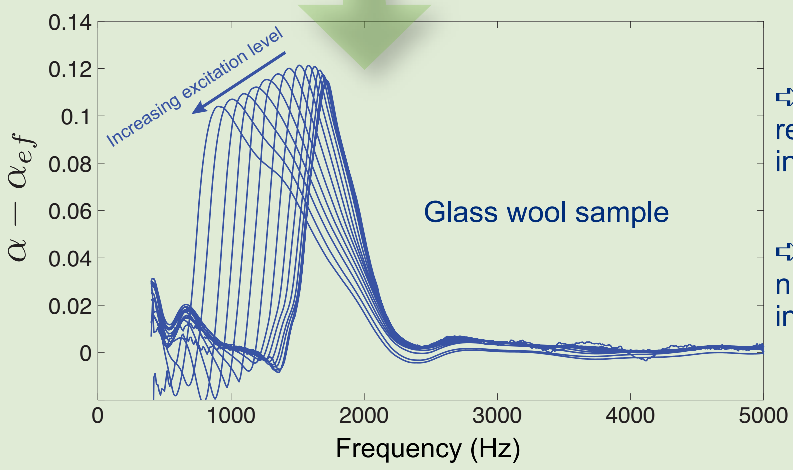



**Fig. 2:** *Absorption coefficient of a glass wool sample obtained with a Kundt tube at acoustic excitation levels from 70 dB to 145 dB.*

Net effect of the Biot resonance on the absorption coefficient

$\alpha_{ef}$ Absorption coefficient in the equivalent fluid case (without the Biot resonance contribution)



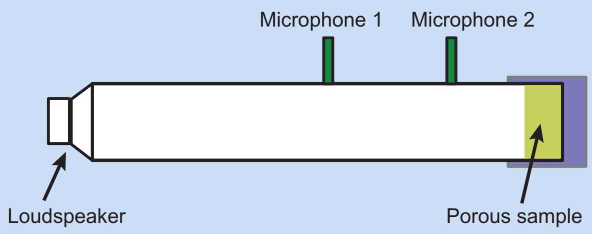

➪ Observation of a downward resonance frequency shift with increasing amplitude

➪ Observation of a diminishing quality factor with increasing amplitude

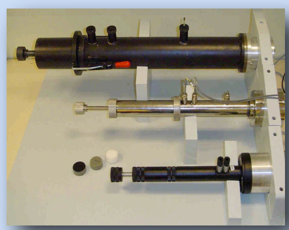
**Fig. 3:** *Net effect of the Biot resonance on the absorption coefficient for excitation levels from 70 dB to 145 dB.*

## Standard measurement of the absorption coefficient

Kundt impedance tube: method of the transfer function




- Step by step increase of the sine wave excitation frequency with feedback on the amplitude to achieve constant acoustic level at the sample
- Excitation levels from 70 dB to 145 dB
- Measurement of the complex impedance Z and reflexion coefficient R of the sample



NF EN ISO 10534-2

Absorption coefficient

$$\alpha = 1 - |R|^2$$

## Analysis of the resonance curves for various samples

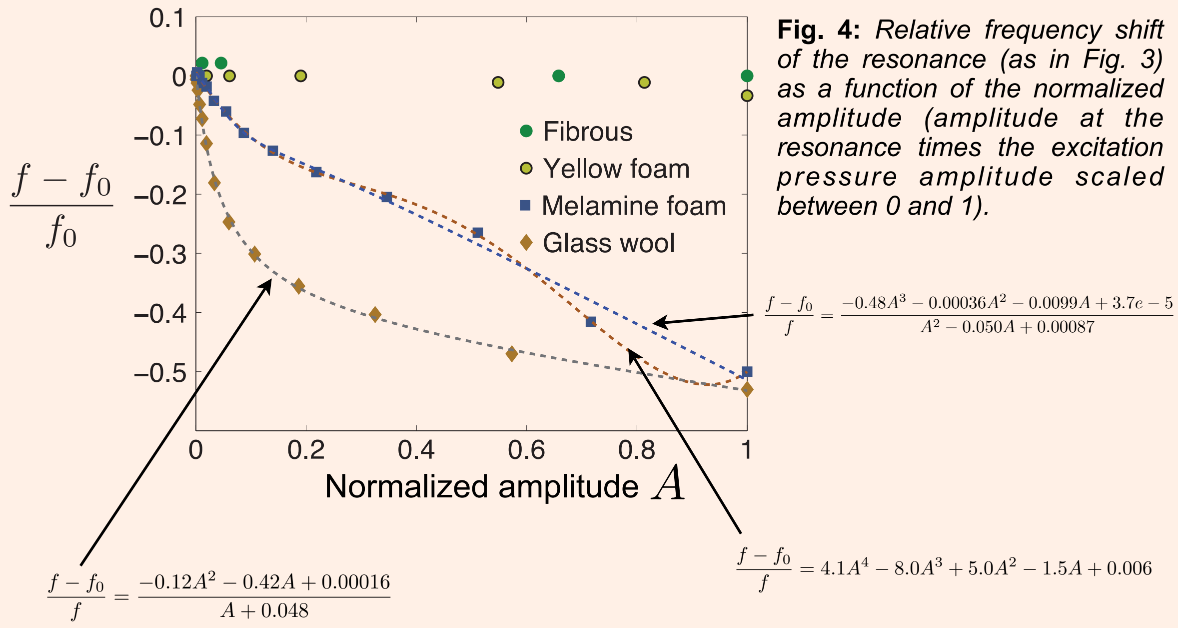



**Fig. 4:** *Relative frequency shift of the resonance (as in Fig. 3) as a function of the normalized amplitude (amplitude at the resonance times the excitation pressure amplitude scaled between 0 and 1).*

➪ Fibrous and yellow foam do not exhibit strong amplitude dependent frequency shift

➪ Attempted fits for melamine foam and glass wool show complex nonlinear behaviors

## Observations / Interpretations

➪ **Different quantitative behaviors** are observed for the downward relative shift in resonance frequencies with increasing acoustic level

➪ At the lowest levels, **a linear resonance frequency shift** is observed. This dependence can be attributed to **quadratic hysteresis** in the stress-strain relationship of the acoustic wave - material interaction

➪ A much more **complex behavior** is observed at **high excitation levels**, depending on the material under test.

➪ **Coupling conditions between the porous medium and the tube** may contribute to the observed nonlinear effects through friction but it has been checked that this is not a dominant source of nonlinearity.

## Conclusions

- Nonlinear effects are only located around the Biot resonance of the sample ➪ they are associated with the solid motion
- Both contributions from the solid skeleton stress-strain relationship and from the air-solid and solid-tube couplings may contribute
- Threshold effects and transitions to different nonlinear regimes suggest activation of complex nonlinear stress-strain relationships (including hysteresis, clapping or buckling for instance)