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# Effect of partial saturation on acoustic properties of nano-porous media

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Nanoporous materials provide high surface area per unit mass and are capable of fluids adsorption. While the measurements of overall amount of fluid adsorbed by a nanoporous sample are straightforward, probing the spatial distribution of fluids is non-trivial. For macro-porous media the effect of partial saturation on acoustic properties is described by the theory of poroelasticity.

To test applicability of poroelastic patchy saturation models to nano-porous materials, we consider ultrasonic measurements during adsorption and desorption of n-Hexane vapor on nanoporous Vycor glass (Page et al., 1995). As vapor pressure is increased from zero to the saturation pressure, the vapor is adsorbed on the pore walls, resulting in gradual increase of the liquid fraction. The reverse process occurs when pressure is decreased, but the 'drying'of the nanopoorus glass is heterogeneous, resulting in a very different velocity-saturation relationship.

On adsorption, we model ultrasonic properties of partially saturated glass using Continuous Random Model (CRM) of Müller and Gurevich (2005), also known as the Dynamic equivalent medium approach (DEMA). In this model, the liquid fraction is considered a random function of position, controlled by the correlation length d ("patch size'), which may itself vary with saturation.

As noted by Kobayashi and Mavko (2016), during imbibition, some significant portion of the liquid fraction should be uniform. In other words, if we consider the medium to be saturated with a binary mixture of two fluids, one of these fluids should be liquid, while the other should be a uniform mixture of liquid and vapor with liquid fraction SL0, which itself increases with the increasing overall liquid saturation SL. This is even more so for nanoporous media, where adsorption tends to produce rather uniform patterns. Our modelling shows that there is a strong coupling between the patch size and uniformly saturated fractions, which cannot be resolved with ultrasonic data only. However, this can be resolved using light scattering data (Ogawa and Nakamura, 2013). Very weak light scattering during adsorption shows that 99.3% of the increase of the saturation is uniform. Yet the saturation is not entirely uniform, as shown by the deviation of the longitudinal modulus from the unform saturation limit (as discussed in the next section).

The desorption process results in macroscopic liquid patches, and cannot be modelled with CRM. We model this process with elastic finite element methods.

Our calculations show that on adsorption the characteristic patch size is of the order of 100 pore diameters, while on desorption the patch size is comparable to the sample size. These results are supported by optical data for similar systems. Our analysis suggests that one can employ ultrasound to probe the uniformity of fluid spatial distribution in nanoporous materials.

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## References

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