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Time-Resolved Schlieren Imaging of Pulsatile Flow in Sinuous-Shaped Constricted Pores

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Traditional porous media wave theory, such as the Biot theory and BISQ model, typically rely on the idealized assumption of smooth cylindrical pores. However, in actual reservoirs, pores often manifest as structures with non-smooth walls and varying diameters, where pores and throats alternate, making them far more complex. These real-world conditions pose new challenges, especially in accurately depicting the impact of fluid flow on wave propagation in these complex structures.

In this work we have proposed a new quantitative research method using the sinusoidal-wall tube model to study fluid flow in porous media. This approach is not only applicable in the field of biomechanics, such as in the description of blood flow, but also in rock physics, especially when considering the dispersion and attenuation effects on wave propagation. A highlight of the work is the introduction of the sinusoidal-wall tube structure, adding an extra dimension to pore geometry, thereby differentiating it from previous porous models. Firstly, we have developed a time-resolved Schlieren imaging system to observe fluid flow in the sinusoidal-wall channel. The optical flow method is used to process the Schlieren images, which enabled us to determine the fluid velocity field quantitatively. Base on the observed velocity field, the fluid pressure field is determined by Naiver-Stokes equations. In addition, we used COMSOL software for numerical simulations, which reproduced the presence of countercurrent and vortex flow in the sinusoidal-wall tubes. These experimental observations and numerical results provide strong evidence of new mechanism for wave dispersion and attenuation in porous media. The results of this research may have a profound impact on rock physics, particularly in understanding the behavior of seismic waves propagating in complex porous media.

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