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Propagation of harmonic flow waves in heterogeneous pipe networks: effect of the pipe radius distribution on the effective wave velocity and attenuation

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Similarly to blood pulse propagation in the artery system, harmonic flow can propagate as a wave in fluid saturated pipes, networks of pipes or, by extension, in porous media, if the fluid is compressible and/or the pipes are elastically deformable. In a previous study, I analyzed the propagation of harmonic flow waves in a cylindrical pipe with a circular cross-section. In particular, the dispersion equation was derived. It was found that, with increasing frequency, the phase velocity followed an S-shape curve, increasing from 0 to the sound velocity in the fluid, while the inverse quality factor decreased from 2 to 0. In networks of pipes, harmonic flow waves are diffracted at each of the branching nodes, causing interferences between forward and backward traveling waves, and thus producing a significant slow down of the resultant wave. This effect depends on the strength of the diffraction points and, consequently, on the variance of the pipe radius distribution. Since the harmonic flow waves described here can be identified with Biot's slow P-waves in porous rocks, these results suggest that the velocity of the Biot's slow P-waves should be affected by the rock pore-scale heterogeneity.