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Attenuation Patterns of Low-Frequency Hydraulic Pulse Waves in Porous Media with Different Permeability

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Hydraulic pulsing is a widely used technology for cleaning, hydro-shredding, and soil improvement. In recent years, low-frequency hydraulic pulses have been used in oil and gas development, such as wellbore blockage removal and EOR. The effectiveness of this process depends on the attenuation pattern of the hydraulic pulse wave in the reservoir. In this paper, a numerical model of low-frequency hydrodynamic pulsed wave propagation in porous media is constructed and experimentally verified. The finite element method was used to solve the model and analyze the radial attenuation patterns of low-frequency hydraulic pulse waves in porous media with varying permeability. The results indicate that the rate of attenuation of the energy (pulse amplitude) of the hydraulic pulse wave with distance is significantly affected by the permeability of the porous medium. The rate of attenuation exhibits a pattern of deceleration, acceleration, and then deceleration again as distance increases. As the hydraulic pulse frequency is 0.1Hz, the pulse amplitude is 10MPa, and, the pulse amplitude attenuates faster along the path as the permeability decreases and is mainly concentrated within 0.5-2.5m around the wellbore. Specifically, the pulse amplitude attenuation to 20% corresponds to a propagation distance of 1.8 m in the 1 mD porous media, 2.7 m in the 200 mD porous media, and 6.8 m in the 1000 mD porous media. The pulse amplitude gradually decreases within 0.5 meters around the wellbore, which may be attributed to the impact of reflected waves. In a porous medium with a permeability of 100 mD, reducing the pulse frequency (0.1-30 Hz) can effectively decrease the interference between different wave levels during propagation and slow down the attenuation rate of pulse amplitude with distance. As distance increases, the effect of pulsation amplitude on attenuation decreases, and the degree of attenuation becomes similar for different amplitudes. For reservoirs with specific permeability, it is recommended to adjust the hydraulic pulse parameters to a lower frequency and higher amplitude to achieve a longer effective distance and better results.

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