Modeling of Attenuation and Dispersion of Elastic Waves in Saturated Porous Media

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SUMMARY

Oil and gas exploration, Biot Theory, and numerical simulation have allowed the development of modeling of elastic wave propagation in environments similar to those found in the exploration of reservoirs, where the Biot Theory can be solved by the finite difference methods. In this paper was modeled the propagation of a plane wave through three models with different porosities of 5%, 10% and 15%, saturated with water. From the modeling, three seismograms were achieved in time, then were analyzed spectrally. Afterwards, the quality factor as a function of frequency and porosity was calculated, also compressional wave velocity as a function of porosity was calculated. Finally it was concluded that the attenuation, dispersion and travel time of seismic waves increases with the porosity and the wave velocity, dominant frequency and quality factor decrease with porosity.
Introduction

By simulating elastic waves propagating in saturated porous media, the phenomenon as attenuation and dispersion are studied, allowing quantify rock-fluid properties, paramount to identify traps and increase productivity in reservoirs (Adam and Wijk, 2014). Using Biot Theory (Biot, 1962a; Duitama and Montes, 2014), whose equations were solved by finite difference methods of second order, the propagation was modeled in depth, the amplitude spectrum were obtained and the quality factor was estimated based on porosity for different frequencies.

Method

The plane wave propagation was modeled throughout three media porosity of 5%, 10%, and 15%, saturated with water. The properties of the rock matrix are Vp of 2146 m/s, Vs of 1169 m/s and density of 2018 kg/m³ and density of 2018 kg/m³. For water Vp of 1500 m/s, density of 1000 kg/m³ and dynamic viscosity of 0.001 Ns/m². Surface source simulated a 30 Hz Ricker wavelet and 7 receptors in depth were located 150 m apart. The model was run with the temporary parameter of dt = 0.00005 s, and space parameter of dx = 1 m.

Results

3 seismograms were achieved (Figs 1a, 1b, and 1c), corresponding to different models of 5%, 10% and 15% of porosity, which were spectrally analyzed (Figures 1d, 1e, and 1f).

Figure 1 (a, b, and c) Seismic wave propagation and (d, e, and f) Amplitude Spectrum

At 1a, 1b, and, 1c sequence, the arrival time of the waves increases with the porosity, indicating decreases in the propagation velocity of wave, also the attenuation effect is evident by decreasing the amplitude of the wavelet with porosity. Furthermore, the effect of dispersion is observed by changing the shape of the wavelet with the depth and porosity. In 1d, 1e, and, 1f sequence, the dominant frequency shift was observed towards low frequencies, showing the effect of attenuation at high frequencies.
Subsequently the Quality Factor as a function of porosity and frequency was calculated, where it was observed that the quality factor decreases with increasing porosity (Figure 2a). It was also noted that the quality factor has the greatest affectation at frequencies above 20 Hz, which shows higher attenuation at high frequencies.

![Figure 2](image)

**Figure 2** a) Quality Factor as a function of Porosity and Frequency and b) Compressional velocity as a function of Porosity.

In Figure 2b, decreasing compressional wave velocity is observed when the porosity increase, because the volume of water in saturated rock increases with porosity.

**Conclusions**

The modeling of wave propagation allowed to observe that the attenuation, dispersion, and travel time of seismic waves increases with porosity. It was also observed that the wave velocity, dominant frequency, and quality factor decrease with porosity.

**References**

