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What can we learn from ultrasonic velocities monitoring during hydraulic fracturing of tight shale ?

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Methods of prediction the size and aperture of created hydraulic fracture are essential for a proper design of unconventional reservoir well stimulation. Several theoretical models describing hydraulic fracture propagation have been developed. However, there is a lack of direct field measurements of hydraulic fracture dimensions, verifying results of these models. Monitoring of elastic wave parameters may be a useful tool to estimate fracture dimensions. Indeed, the elastic wave velocity in a medium containing a fracture is sensitive to the fracture geometry and its conditions: dry fracture or saturated with fluid.

In this paper, we focus on ultrasonic velocities monitoring during hydraulic fracturing of tight shale. We report the results of hydraulic fracturing of Niobrara shale outcrop block of 279 x 279 x 381 mm size from Colorado, USA. In this experiment, the block was loaded in a polyaxial loading frame made by TerraTek, a Schlumberger Company. Stresses were applied to the rock blocks independently in three directions using flat jacks. Then viscous fluid was injected into borehole at a constant flow rate. 20 PZT sensors were embedded into pockets drilled in the rock. They were used for registration of Acoustic Emission (AE) signals and for periodical ultrasonic transmissions to measure P-wave velocities in different directions.

Our results show that ultrasonic measurements can be useful for understanding the mechanics of the crack growth. More precisely, from the evolution of the P-velocities and their amplitudes during the loading, we are able: (i) to estimate the velocity of the hydraulic fracture which was found to be 0.15 mm/s (that is close to the fracture velocity inferred from the dynamic of AE spatial evolution). (ii) In addition, the evolution of the P-velocities during the loading shows that a liquid-free crack always precedes the liquid front. In our experiment, the lag is estimated to be 15 mm. (iii) Finally, at fixed distances from the borehole, we were able to predict the aperture of the hydraulic fracture, and its evolution during the loading. For example, at 10 cm from the borehole, the aperture reaches a value of 1mm at the moment of wellbore pressure breakdown and decrease slightly down to 0.9 mm during fluid pressure drop.

These results shows that ultrasonic velocities monitoring can yield direct measurements of fracture width, length and dynamic of propagation. These inferred properties of the hydraulic fracture can also provide verification of the results of various theoretical models describing fracture propagation.