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Research Article

Shale-gas well test analysis and evaluation after hydraulic fracturing by stimulated reservoir volume (SRV)

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Abstract

At present, there are a lack of mature and accurate analysis methods for post-frac evaluation and productivity prediction of shale reservoirs after hydraulic fracturing by stimulated reservoir volume (SRV). And the application is limited if only one method is used for evaluation, such as micro-seismic monitoring and pump-off drawdown test. In this paper, the fracture network morphology formed by SRV and the expected stimulation results were analyzed. Then, the stimulation results of SRV in shale gas wells were presented by sections by "semi-length of shorter effective fracture + higher effective permeability in SRV" method, so as to stress the forms of main fracture channels near the wells. The radial flow inside the SRV cannot be described by using the traditional multiple, long and straight areal fracture model. This problem was solved after the stimulation results of SRV which was cut and broken by complicated, dense fracture systems moderately far from the wells were described equivalently based on the concept of average effective permeability. As a result, the improvement effects of seepage capacity inside the SRV contributed by hydraulic fracturing were evaluated more rationally, and the productivity was predicted more accurately and stably. This method was applied in a shale-gas horizontal well fracturing in Weiyuan block, Sichuan Basin. It is shown that the seepage performance of fracture networks generated by SRV fracturing is quite different from that of surface source fractures, and it is more similar to the point source flow with perforations or near-well main fracture channels as the center. Besides, well test performance presents the characteristics of radial or pseudo-radial flow instead of linear flow. And the SRV can also be characterized by using the shorter main fracture length and the effective permeability which is several orders of magnitude higher than that of shale matrix.
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Keywords: Hydraulic fracturing; Stimulated reservoir volume (SRV); Well test analysis; Radial flow; Drawdown test; Micro-seismic monitoring; Fracture network; Diagnostic fitting; Sichuan Basin

Hydraulic fracturing by stimulated reservoir volume (*SRV*) is an effective technique for the stimulation of shale gas wells through fracturing. When effective flow channels within tight shale reservoirs are created, the productivity may be maximized and a reliable long-term productivity may be established by SRV. At present, real-time micro-seismic monitoring during fracturing, and interpretation through pump-off drawdown test after fracturing are carried out to identify, analyze and assess the performance of SRV fracturing operations.

However, the results of micro-seismic monitoring are subject to impacts of multiple factors. Density and positions of geophones, undesirable noises during fracturing, accuracy in micro-seismic interpretation and others may induce errors in micro-seismic data interpretation. In addition, micro-seismic monitoring data can reflect rock breaking events and energy responses during fracturing but can hardly identify fractures with effective conductivity accurately, since stimulated reservoir volume obtained through micro-seismic interpretation is often much larger than effective stimulated reservoir volume controlled by a well. Pump-off drawdown test during fracturing is also a key technique available for interpretation of fractures. However, since the test is usually performed within a

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limited time period, the data points acquired are insufficient to record the transmission of pressure waves in the effective stimulated reservoir volume, making the quantitative description of fracture network morphology difficult.

By using post-frac flow and pressure data in shale gas wells, well tests can be performed to analyze the flow behavior of fluids and highlight the morphology of fractures or fracture networks generated through hydraulic fracturing, to assess geometric parameters, conductivity, effective stimulated reservoir volume and effective permeability of fractures quantitatively. All these data may provide more detailed and accurate information for the assessment of stimulation performance and the prediction of productivity [1,2].

However, descriptions based on cross-cutting of horizontal wellbore by multiple horizontal fractures adopted by conventional well test models for staged fracturing horizontal wells may reflect fracture morphology significantly different from those produced by SRV fracturing for shale gas development. In addition, these conventional well test models may not describe the patterns of certain flow fields observed during production. Under such circumstances, significant deviations can be observed during assessments for effective fracture lengths and effective permeability in the stimulated reservoir volume upon the completion of SRV fracturing. Eventually, such deviations may result in prediction conclusions dramatically different from those observed on site.

In this paper, the fracture network morphology formed by SRV fracturing and the expected stimulation results were analyzed. Then, the stimulation results of SRV fracturing in shale gas wells were presented by sections by "semi-length of shorter effective fracture + higher effective permeability in stimulated reservoir volume" method, so as to stress the forms of main fracture channels near the wells. The radial flow inside the stimulated reservoir volume cannot be described by using the traditional multiple, long and straight areal fracture model. This problem was solved after the stimulation results of fractured volume which was cut and broken by complicated, dense fracture systems moderately far from the wells were described equivalently based on the concept of average effective permeability. As a result, the improvement effects of seepage capacity inside the stimulated reservoir volume contributed by SRV fracturing were evaluated more rationally, and the productivity was predicted more accurately and stably [3].

1. Shale-gas well fracturing by stimulated reservoir volume (SRV)

The objective of hydraulic fracturing by stimulated reservoir volume (SRV) in a shale gas well is to make complex networks of conductive fractures arranged in a crisscross pattern in a shale reservoir [1] (wide fracture conductive network) formed to achieve sufficient breaking and cutting of the shale reservoir spatially. In addition, fractures with various conductivities are combined to generate an integral system with desirable configuration of supply and transport capabilities. Sufficient attentions should be paid to the following aspects during shale gas SRV fracturing stimulation. ① High flow rate is deployed during injection to maintain net fracture pressure formed to achieve the maximum breaking performance under allowable fracturability. ② Low-viscosity slickwater and gel with certain viscosity are used jointly to ensure the extension of fractures perpendicular to the direction of the borehole and to achieve proper extension of fracture network widths along the borehole. ③ Proppants with different diameters are used to maintain fractures of various sizes. In this way, combination of multi-level conductivities can be obtained. ④ Degradable temporary plugging additives are deployed to minimize filtration and divert the fractures so that the fluid-conducting efficiency and the complexity of the fracture network are enhanced.

With the SRV fracturing of Well A for shale gas development in Weiyuan block, Sichuan Basin as an example, the following techniques should be considered:

① Combination of slickwater and active gel
② Combination of proppants in 100 mesh, 40/70 mesh and 30/50 mesh to achieve desirable conductivities at three levels generated by micro-fractures, branch fractures and main fractures

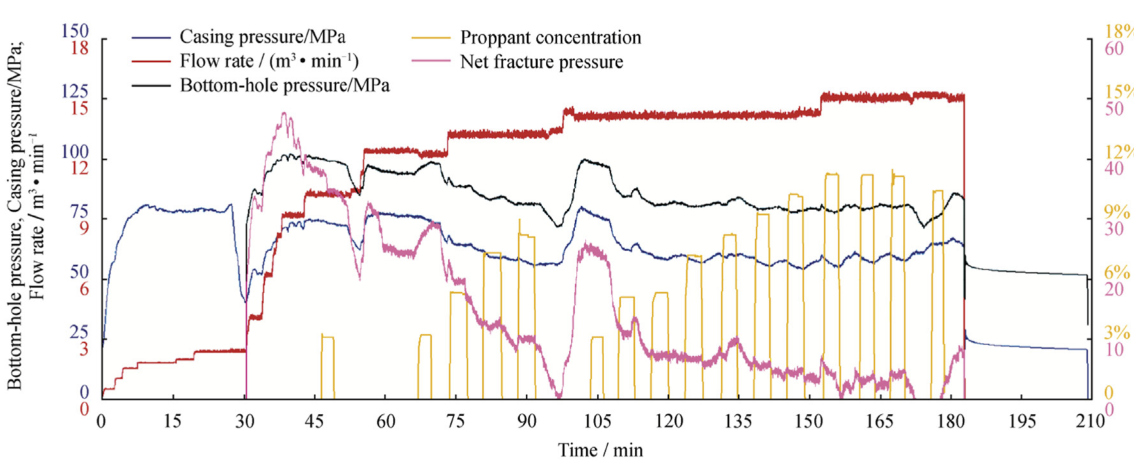

Fig. 1. Typical curves of wide fracture conductive networks after hydraulic fracturing by stimulated reservoir volume (SRV) in Well A.

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