Research on the Hydraulic Fracturing Design of Polygenetic Compound Oil-Gas Reservoirs

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1 Polygenetic Compound Oil-Gas Reservoirs

Metallogeny is a discipline that differs with ore mineralogy. Its prominent feature is that it’s a marginal discipline which conducts its researches by combining the formation of ore deposits with the regional tectonic evolution (Chen, 1987). Due to the concept of polygenetic compound deposits embodies the 4-dimension thinking (Chen, 1982) which is emphasized by historic-dynamic geotectonics to take into account both time and the 3-dimension space, such deposits are well-known for their multi-stage metallogenetic geotectonic evolution (Chen, 2000). Polygenetic compound oil-gas reservoirs are a major type of polygenetic compound deposits (Wei, 1988). About the various kinds of China’s geotectonic oil fields, Chen (1983; 1988) has presented a systematic classification concerning their reservoir features, forming mechanisms and distribution patterns. Platform type oil-gas fields normally form at the platform depression or subsidence area, with wide-spreading oil-bearing layers and frequently seen as the placanticline or dome-shaped reservoirs. Daqing Oil Field is the archetype. Geodepression type oil-gas fields mostly form in continental depression basins, with the cracked arch and faulted blocks being their typical form. Such reservoirs are relatively small, but their number is large with many source beds and oil-bearing layers. The current situation for polygenetic compound oil-gas reservoirs is that most of them in East China have entered the mid or late stage of water flooding procedure or even the tertiary recovery.

2 The Reservoir Heterogeneity of Polygenetic Compound Oil-Gas Reservoirs

The development process of oil-gas oil reservoirs is a dynamic coupling one between multi-phase flowing fluids and reservoir rocks. Especially, when a reservoir is in its late stage of high water content, the fluid-solid coupling effect reaches its highest. This is mainly because the reservoir porosity and permeability vary according to the changing effective pressure in this stage. In their development, correctly recognizing their reservoir heterogeneity, and determining changes of their petrophysical properties, stress field and oil saturation content are the key steps.

Researches conducted on features of micro-facies and their heterogeneity, flow characteristics in mid or late stage of development, reservoir petrophysical properties, fluid flow mechanisms, and discontinuous flow simulation revealed that formation thickness, lateral or vertical extension of oil layers all possess severe heterogeneity. The flow field in layers or the whole reservoir is confined within boundaries. Within an individual reservoir, the parameters of its flow field is not uniform everywhere, however, it consists of independent flow units with different flow patterns. The heterogeneity of fluid storage space and that of fluids’ distribution constitutes an extremely complex world for the flow field both laterally and vertically. In the mid or late stage of field development, with the increasing injection pressure, the exchange of ions between different fluids and surrounding rocks continues, which results in alternating dissolving and sedimentation. Thus, a certain proportion of pores will be filled and blocked; consequently, this renders low permeability. As the injection pressure and the water content increase, the shear strength of rocks also decreases sharply. The heterogeneous change in petrophysical properties, mechanical properties, and flow field distribution will inevitably affect the distribution of formation pressures, which further influences the in-situ stress field. Therefore, studying the heterogeneity of polygenetic compound oil-
gas reservoirs can usefully guide formation hydraulic fracturing design (Leng et al., 2003).

3 Hydraulic Fracturing Design of Polygenetic Compound Oil-Gas Reservoirs

With the continuous development of reservoirs and their gradual increasing water content, the developing difficulty becomes more and more striking, especially for thin and poor quality oil layers from commercial reserves and noncommercial reserves. Such formations are characterized by excessive thin oil layers and interlayers, low porosity; therefore, they are almost impossible to be utilized without proper hydraulic fracturing. In order to enhance reserve producing degree and recovery rate, hydraulic fracturing needs to be implemented (Xiao et al., 2012). As for polygenetic compound oil-gas reservoirs, characterized by the small well spacing and complex distribution of in-situ water, most formerly carried-out hydraulic fracturing procedures neglected researching on hydraulic fractures’ planar distribution characteristics formed under complex in-situ stress field and verifying petrophysical properties; and, also failed to take into account structures and features of such reservoirs. The resulting hydraulic fractures lead to early water breakthrough or low oil well productivity.

Considering the coupling effect between formation pressures and fluid pressures in different development stages of polygenetic compound oil-gas reservoirs, this article established a fluid-solid coupling nonlinear flow model and a rock mechanics model. By using numerical simulation techniques to simulate the planar distribution characteristics of formed hydraulic fractures and in-situ stress field and discussing the relationship between hydraulic fractures’ geometry and in-situ stress field, hydraulic fracturing schemes were designed for these reservoirs, which enhanced the effectiveness of field development.

4 Conclusions

Oil fields located in East China most are polygenetic compound oil-gas reservoirs. Based on the characteristics of these reservoirs, studying their heterogeneity, flow field and stress field, designing corresponding hydraulic fracturing schemes, can effectively enhance oil recovery.

Reference