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Numerical Simulation of Hydraulic Fracture Propagation in Marine-continental Transitional Tight Sandstone Reservoirs by Boundary Element Method: A Case Study of Shanxi Formation in China

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Abstract : After years of research, offshore oil and gas development now are shifted to unconventional reservoirs, where multi-stage hydraulic fracturing technology has been widely used. However, the simulation of complex hydraulic fractures in tight reservoirs is faced with geological and engineering difficulties, such as large burial depths, sand-shale interbeds, and complex stress barriers. The objective of this work is to simulate the hydraulic fracture propagation in the tight sandstone matrix of the marine-continental transitional reservoirs, where the Shanxi Formation in Tianhuan syncline of the Dongsheng gas field was used as the research target. The characteristic parameters of the vertical rock samples with rich beddings were clarified through rock mechanics experiments. The influence of rock mechanical parameters, vertical stress difference of pay-zone and bedding layer, and fracturing parameters (such as injection rates, fracturing fluid viscosity, and number of perforation clusters within single stage) on fracture initiation and propagation were investigated. In this paper, a 3-D fracture propagation model was built to investigate the complex fracture propagation morphology by boundary element method, considering the strength of bonding surface between layers, vertical stress difference and fracturing parameters (such as injection rates, fluid volume and viscosity). The research results indicate that on the condition of vertical stress difference (3 MPa), the fracture height can break through and enter the upper interlayer when the thickness of the overlying bedding layer is 6-9 m, considering effect of the weak bonding surface between layers. The fracture propagates within the pay zone when overlying interlayer is greater than 13 m. Difference in fluid volume distribution between clusters could be more than 20% when the stress difference of each cluster in the segment exceeds 2MPa. Fracture cluster in high stress zones cannot initiate when the stress difference in the segment exceeds 5MPa. The simulation results of fracture height are much higher if the effect of weak bonding surface between layers is not involved. By increasing the injection rates, increasing fracturing fluid viscosity, and reducing the number of clusters within single stage can promote the fracture height propagation through layers. Optimizing the perforation position and reducing the number of perforations can promote the uniform expansion of fractures. Typical curves of fracture height estimation were established for the tight sandstone of the Lower Permian Shanxi Formation. The model results have good consistency with micro-seismic monitoring results of hydraulic fracturing in Well 1HF.

Keywords : fracture propagation, boundary element method, fracture height, offshore oil and gas, marine-continental transitional reservoirs, rock mechanics experiment
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