

Evaluation of Cyclic Steam Injection in Multi-Layered Heterogeneous Reservoir

Authors : Worawanna Panyakotkaew, Falan Srisuriyachai

Abstract : Cyclic steam injection (CSI) is a thermal recovery technique performed by injecting periodically heated steam into heavy oil reservoir. Oil viscosity is substantially reduced by means of heat transferred from steam. Together with gas pressurization, oil recovery is greatly improved. Nevertheless, prediction of effectiveness of the process is difficult when reservoir contains degree of heterogeneity. Therefore, study of heterogeneity together with interest reservoir properties must be evaluated prior to field implementation. In this study, thermal reservoir simulation program is utilized. Reservoir model is firstly constructed as multi-layered with coarsening upward sequence. The highest permeability is located on top layer with descending of permeability values in lower layers. Steam is injected from two wells located diagonally in quarter five-spot pattern. Heavy oil is produced by adjusting operating parameters including soaking period and steam quality. After selecting the best conditions for both parameters yielding the highest oil recovery, effects of degree of heterogeneity (represented by Lorenz coefficient), vertical permeability and permeability sequence are evaluated. Surprisingly, simulation results show that reservoir heterogeneity yields benefits on CSI technique. Increasing of reservoir heterogeneity impoverishes permeability distribution. High permeability contrast results in steam intruding in upper layers. Once temperature is cool down during back flow period, condense water percolates downward, resulting in high oil saturation on top layers. Gas saturation appears on top after while, causing better propagation of steam in the following cycle due to high compressibility of gas. Large steam chamber therefore covers most of the area in upper zone. Oil recovery reaches approximately 60% which is of about 20% higher than case of heterogeneous reservoir. Vertical permeability exhibits benefits on CSI. Expansion of steam chamber occurs within shorter time from upper to lower zone. For fining upward permeability sequence where permeability values are reversed from the previous case, steam does not override to top layers due to low permeability. Propagation of steam chamber occurs in middle of reservoir where permeability is high enough. Rate of oil recovery is slower compared to coarsening upward case due to lower permeability at the location where propagation of steam chamber occurs. Even CSI technique produces oil quite slowly in early cycles, once steam chamber is formed deep in the reservoir, heat is delivered to formation quickly in latter cycles. Since reservoir heterogeneity is unavoidable, a thorough understanding of its effect must be considered. This study shows that CSI technique might be one of the compatible solutions for highly heterogeneous reservoir. This competitive technique also shows benefit in terms of heat consumption as steam is injected periodically.

Keywords : cyclic steam injection, heterogeneity, reservoir simulation, thermal recovery

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