Evaluating Horizontal Multistage Fracture Well Placement in Low Permeability Reservoir

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Abstact. Well spacing is a critical factor to figure out when planning to drill new wells in low permeability reservoirs. In this paper, horizontal multistage fractured well spacing is optimized for several scenarios in H reservoir using PEBI grips. To find the optimum well spacing, sensitivity analyses are carried out first to find the most influential fracturing parameters. Orthogonal experiment is used to scheme scenarios which incorporates sensitive parameters. The results show that fracture number and fracture conductivity exert significant impacts on oil recovery. The best spacing for the finite reservoir is 6000ft.

Introduction

Fracturing technology has been developing rapidly in recent years. Both the size and sophistication of field treatments have increased dramatically. The development of low permeability reservoir can utilize advantages of fracturing technology[1]. Compared to normal fracturing technology, horizontal, multistage fractured wells increases the reservoir contact and effective drainage area and provides a highly conductive path to the wellbore[2]. In this study, H oilfield would be analyzed. H oilfield is a typical low permeabilitytight sandstone reservoir. There are three major depositional systems classified for the depression: salt lake delta, underwater fan and salt lake subfacies. H oilfield was developed from 1977. At present, the current oil recovery has been up to 31.84% and water cut for overall wells has reached up to 61.3%. Although the recovery and water cut of the oilfield is all higher, there is still some remaining oil in its boundary and corner zones, multi-directional water squeezing zones and local low permeability zones, and reservoir engineers should target on these potential zones. PEBI gridsis used to optimize well placement study. PEBI grids is capable of controlling errors of flow calculation, and can be used to model structurally highly complex reservoirs in two and three dimensions. Besides, flow feature of the multistage fractures can be modeled better by PEBI grids[3]. Non-Darcy flow is considered in the simulation. In this study, mature commercial simulator is used. The basic parameters for this model are described in Table1.
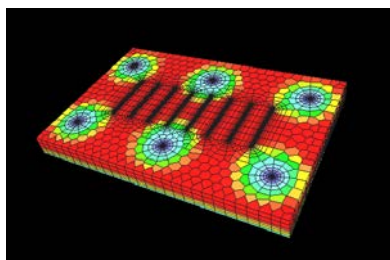

Fig. 1 PEBI grids model

Table 1 Settled reservoir, oil, water, well and hydraulic fracture data

Parameter	Value
Porosity, φ （%）	16
Reservoir permeability, k(md)	17
Reservoir depth, (ft)	7000
Reservoir thickness, (ft)	30
Rock compressibility, cf(psi-1)	3.0E-6
Reservoir temperature, Tr(°F)	200
Reservoir vertical-to-horizontal anisotropy ratio	0.1
Oil viscosity, μ_o （cp）	3.5
Water viscosity, μ_o （cp）	0.30
Horizontal well length, Lh(ft)	3000
Wellbore radius, rw(ft)	0.3
Average fracture width, Wf(inch)	0.25

Sensitivity Analysis

Some fracture parameters are chosed to check their influence on a horizontal well's produce performance. The results show that fracture half-length, fracture number and fracture conductivity are key parameters for optimization well spacing. Thus sensitivity experiment is carried out to examine these parameters' sensibility. Pragmatic range of these parameters will be selected based on H oilfield. Cumulative oil production is used to evaluate the difference caused by fracture parameters. In order to eliminate well interference, simulation runs on a single well model within a 20000×20000ft reservoir model.

Table 2 Parameters of hydraulic fracture

Parameter	Value
Fracture half-length, X_f(ft)	100, 200, 300
Fracture number, N_f	4, 8, 12
Fracture conductivity, C_f(md.ft)	10, 100, 500

Fracture Characteristics. Number of fracture and fracture half-length are considered in the sensitivity experiment. The range of X_f, N_f and C_f are presented in Table2. In the sensitivity experiment, the simulation runs were simulated with model data provided in Table1 along with the following properties: X_f of 200ft, N_f of 8, C_f of 100.
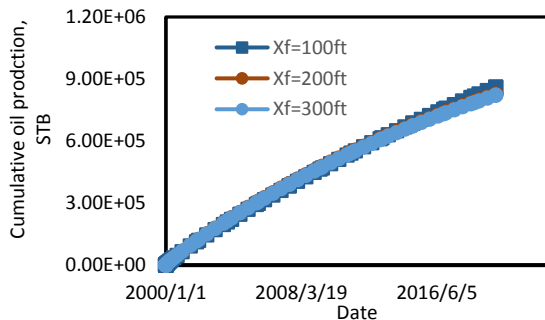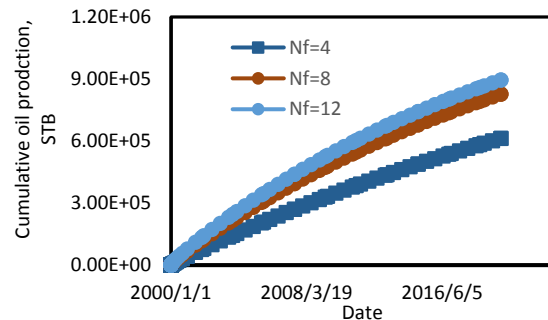

Fig.2 Sensitivity results of different fracture length

Fig. 3 Sensitivity results of different fracture number

The simulation results of sensitivity examination for fracture half-length areshowed in Fig2. The plots indicate that fracture half-length cannot exert significant impacts on reservoir recovery.In contrast tolong distance of pressure drop, fracture half-length is comparatively short. Thus Fig.2 shows mild difference among three scenarios.Hence, the relation between fracture half-length and cumulative oil production should be neglected in the later study.

Fig.3 describes cumulative oil production vs. time for 4, 8 and 12 fractures. The results show that the numbers of fractureaffect oil production. Compared to normal horizontal well, horizontal multistage fracture well promotes oil production tremendously. However, the difference of cumulative production will be decreased when fracture number are augmented to an extent. When horizontal well length is fixed, there is a critical value offracture number exists. Field engineers should spend least cost to obtain highest oil recovery. All in all, number of fracture should be considered in optimization study.

Furthermore, the last fracture property considered for sensitivity study is fracture conductivity. Fig.4 shows that larger cumulative production is obtained from horizontal wells with higher fracture conductivity. Thus, when fracture conductivity is low, pressure drop is not enough for oil to flow toward the fractures. Fracture conductivity is considered as a sensitivity variable in optimization study.
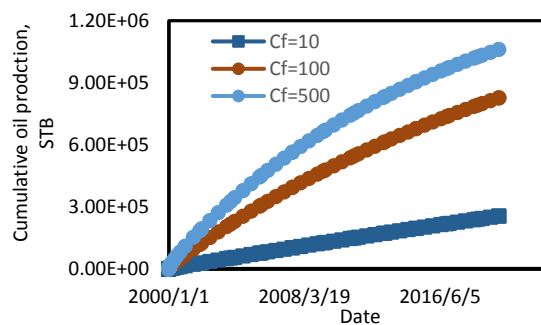

Fig. 4 Sensitivity results of differentfracture conductivity

Well Spacing Optimization

Well spacing is a crucial parameter which would be considered in horizontal fracture multistage well design. Well spacing should be studied to obtain optimum production and economic benefit. In this well spacing study, five-point well pattern is used, since five-point well pattern is typical develop well pattern for low permeability reservoir. As what have been discussed above, fracture number and fracture conductivitywould be considered in the optimization study. The well distance about 4000, 6000 and 10000ftare considered in the simulation. These models would be run in 50000 ×50000ft reservoir model.Orthogonal experimental design which could analyze effect of several factors comprehensively isgiven to plan different scenarios.These scenarios and simulation results are showed in Table3.

The results of orthogonal experimentare analyzed via visual analysis method. The average value of fracture number and fracture conductivity prove that the sensitivity experiment's results are correct. The average cumulative production of 4000, 6000 and 10000ft well distanceare 3444048, 3472100, 3069794 STB, Theresultsof visual analysis indicates that cumulative oil production of 4000 and 6000ft well distance are approximately equal values. The reasons for that aredue to small well distance would lead to several wells sharing drainage area together and well interference would be caused. And short well distance would cause that wells could not deplete what they arecapable of.

No matter of economic concerns or technological concerns, compared to the scenario that well distance is 4000ft, 6000ft well distance is more suitable for the reservoir. On the other hand,dead oil zone would be generated when well spacing is too large.And injection control area cannot cover horizontal well completely. Thus well recover efficiency have not been maximized. That is the reason why cumulative production of 10000ft well distance was lower than 6000ft well distance.

Table3 Scenarios of orthogonal experiment

	well distance(ft)	C_f(md.ft)	N_f	cumulative production(STB)
scenario1	4000(1)	10(1)	4(1)	894558
scenario2	4000	100(2)	8(2)	4249514
scenario3	4000	500(3)	12(3)	5188076
scenario4	6000(2)	10	12	1343007
scenario5	6000	100	4	4523982
scenario6	6000	500	8	4549313
scenario7	10000(3)	10	8	1640543
scenario8	10000	100	12	2809481
scenario9	10000	500	4	4759360
average value of(1)	3444048	1292702	2751117	
average value of (2)	3472100	3860991	3450626	
average value of (3)	3069794	4832249	3784200	

Conclusion

Optimum well spacing is strongly governed by fracture properties. Simulation results shows that fracture number and fracture conductivity are critical to optimum well spacing. Nevertheless, fracture half-length doesn't play a significant role in optimization. The orthogonal experiment results indicated 6000ft well distance are most suitable scheme among those scenarios. Too large well distance generates dead oil zone and is hard for injection well plays its role effectively. Too small well distance causes well interference and leads to contracted overall drainage area.

References

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